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ABSTRACT

Presented in this 1972-1973 annual report are summaries of projects in advisory services, coastal zone studies, fisheries and aquaculture, marine products, and ocean engineering. A listing of publications and an activity budget are included. The report is intended to be a general overview of the total activities of the University of California's Sea Grant College Program. (Author/EB)

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UNIVERSITY OF CALIFORNIA SEA GRANT COLLEGE PROGRAM ANNUAL REPORT 1972-1973

A report on the University of California Sea Grant College Program for September 1, 1972, to August 31, 1973.

2

SE 019 491

September 1, 1972, to August 31, 1973

Sea Grant U-California

UNIVERSITY OF CALIFORNIA
SEA GRANT COLLEGE PROGRAM
ANNUAL REPORT
1972-1973

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INTRODUCTION

1972-73 has become a landmark year in the brief history of the University of California Sea Grant Program with the August announcement by Secretary of Commerce Frederick Dent that the University of California had been selected for designation as the nation's seventh Sea Grant College. This designation, according to the Office of Sea Grant, is based on quality, quantity and productivity of performance by the institution in the categories of research, education, and advisory services; the degree and nature of cooperation with and service to its marine communities; the exercise of leadership in the institution's conduct over a period of not less than three years under Institutional Support; and the efficiency and competence of its Sea Grant program management.

"The designation Sea Grant College symbolizes a mutual recognition of continuing responsibility both by the Department of Commerce and the institution so designated, to develop and maintain the excellence and public utility of the institution's Sea Grant program.

"By the award of Sea Grant College status, the Department of Commerce expresses its confidence in the demonstrated dedication and competence of the Sea Grant College by assigning priority of support to the College, within the limits of overall Federal priority and fiscal considerations, renewable as continued performance by the College may warrant.

"The Sea Grant College accepts with such designation the responsibility for the continued pursuit of excellence in marine research, education, and public service, through advisory programs, and the exercise of leadership in its region in assisting and supporting other institutions and agencies, both public and private, in the development of programs for the proper use and protection of the marine environment."

Credit for this achievement is shared by Sea Grant participants at seven University of California campuses, San Diego State University, the University of San Diego, and the Southwest Fisheries Center of the National Marine Fisheries Service. Clearly, the enthusiasm, planning, and persuasion of Dr. George G. Shor, my predecessor as Program Manager, in effecting the policies and guidance of the Sea Grant Coordinating Council has had a great deal to do with the success of this innovative program which cuts across established institutional and disciplinary lines.

While the direct intent of this publication is to report project work and advisory activity during the year 1972-73, it is hoped that it will spark new questions with regard to other aspects of our management and utilization of marine resources that will lead to useful new investigations and services. The scientific and academic resources potentially available within the California community to meet Sea Grant objectives are almost unique in scope and quality. The task is to correctly identify public interest priorities and the personnel best equipped to deal with them.

It is the continuing objective of the University of California Sea Grant program to direct our best human resources and facilities toward solution of marine resource development and management problems. Your advice and assistance are invited.

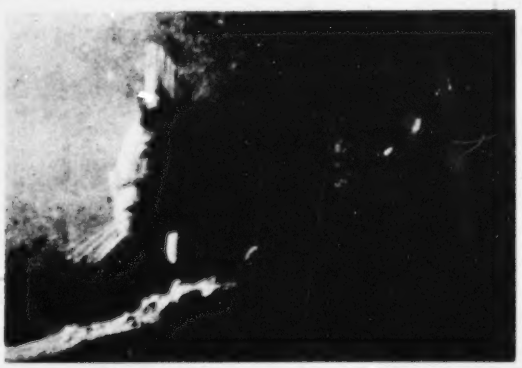
Jeffery D. Frautschy
Sea Grant Program Manager

Fishing captains and advisory personnel.

ADVISORY SERVICES

The advisory programs are committed to establishing and maintaining communications among teachers, researchers, and users and students of the marine environment and the ocean resources. The objectives are to seek out information on marine resource needs, to respond directly to them with practical technology and useful innovations, to supply basic resource information, and to advance the understanding and appreciation of the ocean and coastal resources.

What is the proper balance between coastal development and protection of shore resources?



Artificial reef habitat from sunken automobile tires.

Marine Extension Service

Davis
A/E-1

Maynard W. Cummings

During this first full year of funding for UC Advisory Services through Cooperative Extension, a Marine Advisory Program Newsletter was begun with an initial mailing list of one thousand readers both within the program and outside. The publication informs professionals and nonprofessionals and stimulates suggestions for program emphasis and requests for assistance.

Reef project

An example of a program "just waiting to happen" was in Ventura County where a local extension advisor guided by the marine resources specialist directed a community effort which constructed an artificial reef for sport fishing. The project involved the County Fish and Game Commission, Port Commission, sportsmen, Explorer Scouts, Optimist and Kiwanis Clubs, community-minded citizens young and old, State Fish and Game Department, and the acquiring of permits for placement of the reef.

Marine Advisory staff directed assembly and placement of tons of concrete-weighted auto and truck tires. The reef will last forever compared to those made from steel car bodies, and diving examinations show that fish have found the new haven. Local fishermen already knew that and when a second reef segment was placed two months after the first one, a photographer recording the activity caught 10 fish in 30 minutes. the reef project was covered by news media and was featured in a Sea Grant display booth at the Ventura County Fair and in a 90-second TV news film of the reef constructoin and placement which was shown throughout the state.

Serving mariners, 4-H, the public, fishermen and industry

A special project was compilation of statewide data published as a Directory of Services for Mariners. This booklet has been widely distributed along the entire Pacific Coast and continues to be complimented and requested. Hawaiian information was included and the publication issued through coordination provided by the regional Pacific Sea Grant Advisory Program.

There are active 4-H Marine Science Projects in at least 15 counties. A series of workshops at which the UC Marine Resources Specialist and a Marine Education Specialist from Oregon State University advisory program, again by regional cooperation, presented 4-H marine program planning and project literature to Extension staff and volunteer leaders was held in coastal counties. There already are 400 4-H members with marine science projects and this number is steadily growing as newly prepared literature is distributed throughout the UC 4-H program. The Marine Resources Specialist and Staff Research Associate have produced California literature expanded from Oregon's early publications in this field. The Director and staff of the Scripps Museum and Aquarium have actively assisted in this program.

A pair of unique, specialized workshops chaired by UC Marine Advisory Programs discussed the potential for California seafood products on the Japanese market. These public seminars held in Los Angeles and San Francisco explained air cargo programs for seafood, the nature of the Japanese market, processing techniques, and potential, largely underutilized California resources such as sea urchins which could be profitably air shipped to Japan. The California Fish and Game Department and Japan Air Lines presented uniquely valuable marketing information to seafood processors, brokers, fishermen, other airline and airfreight specialty representatives, and to National Marine Fisheries personnel. Participants' responses were enthusiastic with industry members of the California Seafood Institute being especially appreciative.

At other meetings, specialized information on local needs was presented by marine advisory staff to such industry groups as the Bodega Bay Fisherman's Association, Half Moon Bay Fishermen's Marketing Association, the Inter-Tribal Council of California, Inc., the California Seafood Institute, San Mateo County Migrant Workers Education Council, Fort Bragg Salmon Trollers Association, San Francisco Tyee Club, Santa Cruz Fisherman's Association and the Mendocino County Planning Department.

A Sand Dune Stabilization Workshop at the Bodega Bay UC Marine Laboratory was attended by representatives from state and county parks, private industry developers and others interested in use of beach grasses and other plant materials to control sand movement and stabilize dunes. A workshop proceedings summarized the information for further distribution.

Trouble-shooting processing problems

The Extension Food Technologist in Marine Advisory Programs worked with many seafood processors trouble-shooting problems involving food poisoning from fish products, fish discoloration, waste disposal, plant sanitation and industry upgrading operations to comply with more stringent application of state and federal sanitation and public health regulations. Consumer groups and Extension Home Advisors were given training in fish and shellfish nutrition, how to select, process, store, and prepare seafoods. Factual information on, and how to analyze and overcome alarmist myths about, food poisoning, mercury, botulism, and other food science subjects was presented at both public seminars and in-service training programs. Among other contributions, the Marine Advisory Program:

- published a tide pool conservation poster, Don't Join the Bucket Brigade, in cooperation with the California Department of Fish and Game.
- recruited and placed an Area Marine Advisor to serve marine resource users in Mendocino, Sonoma and Marin Counties and the San Francisco Bay complex; he will work with coastal planning groups and developers, marine businessmen, sport and commercial fishermen, fish and shellfish harvesting and processing, youth and adults interested in marine science education.
- developed and maintained rapport with marine agency, governmental and clientele groups by providing communication and technical information.
- participated in cooperative technical sessions such as those of the Pacific Marine Fisheries Commission, Albacore Ad Hoc Committee, Federal State Dungeness Crab Study.
- presented a paper at the 5th National Sea Grant Association Conference at Houston.
- developed liaison for informational function to the Central Coastal Conservation Commission by the closely knit programs in their area of the Moss Landing Marine Laboratories and the County Cooperative Extension offices.
- participated in the planning and cooperative activities of the regional Pacific Sea Grant Advisory Program.
- used radio, television and other mass media in marine resource conservation program education.
- made talks before University, civic and educational organizations and service clubs.

Coordination effort of MAP staff

Significant progress was made in guidance of and participation in both CMAP cohesiveness and NMAP establishment. CMAP, California Marine Advisory Programs, is the coordination effort of Marine Advisory staff of the University of California, University of Southern California, California State University, Humboldt and Moss Landing Marine Laboratories to function as a unit insofar as practicable in developing and distributing information and in presenting a unified reception to public inquiry directed back to Sea Grant. The CMAP staff members meet regularly, confer informally as necessary and plan joint programs where feasible. NMAP, the agency-wide NOAA Marine Advisory Programs, is beginning to serve in coordinated fashion, particularly the National Marine Fisheries Service and Sea Grant advisory program personnel.

In other agency cooperative efforts, excellent rapport is enjoyed with the California Department of Fish and Game and Department of Navigation and Ocean Development, and the many county governments involved in coastal programs.

Intra-University of California program development prospers with the increased liaison between Sea Grant and Cooperative Extension and by the presence of California State University, San Diego and Moss Landing Marine Laboratories as integral components of UC Sea Grant.

Publications and Public Advisory Services

San Diego
A/P-1

Gerald L. Wick

During 1972-73, we began to establish ourselves as an information, publishing and publications resource for California Sea Grant, National Sea Grant and many different publics—lawmakers, scientists, and concerned lay persons throughout the world.

The Publications office continued its publishing of the Marine Technicians Handbook, issuing to more chapters, "Rock-Dredging in Deep Areas" and "The Curating of Marine Geological Samples."

In March, 1973, a bimonthly newsletter was launched to an audience including all California Sea Grant participants, state and national legislators, other Sea Grant programs and a still-growing list of interested readers.

The first professionally designed Annual Report was published and an effort was made to strike a balance between lay and technical language to accommodate our wide readership.

We published a directory of the 46 1972-73 UC Sea Grant projects, which included project locations (by campus), principal and associate investigators, and research summaries and compiled, in cooperation with the University of Southern California, a cumulative directory of Sea Grant research throughout California.

We distributed reprints of scientific articles resulting from UC Sea Grant sponsored research special technical reports, such as "Sea Floor Work Economics," a preliminary report on sea floor exploration equipment.

We prepared news releases on special projects and events which were handled by the regular campus public information office.

Ocean Engineering Data Center

Berkeley
A/DC-1

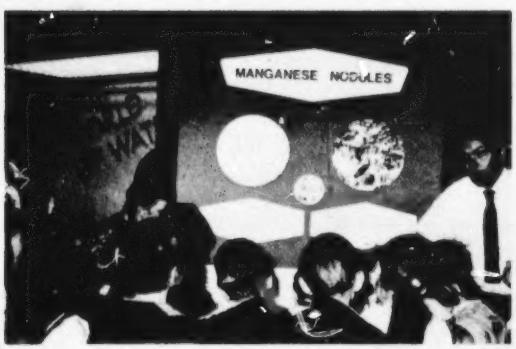
Joe W. Johnson

A collection of literature in the field of ocean engineering, assembled over the past twenty years by several members of the faculty of the Department of Engineering, University of California, Berkeley, was recognized as being a valuable source of ocean engineering data. This collection, totalling approximately 20,000 titles, had been recently moved to the premises of the Water Resources Center Archives for administration where it was made available for the use of interested researchers. The collection continues to be added to and will reflect current research. This Sea Grant project has been concerned with making the collection more accessible.

EDUCATION AND TRAINING

In its support of UC education programs, Sea Grant has facilitated the development of the Applied Ocean Science curriculum at Scripps, a graduate program with a focus on identifying, understanding, and solving applied marine problems.

Fanning or curing the sea fever of undergraduates with oceanographic ambitions by exposing them to shipboard research life; opening the door of ocean studies and making ecology an abiding concern instead of a fad for schoolchildren and adult visitors at the Scripps Aquarium-Museum, ocean education becomes the province of everyone in UC Sea Grant.



Graduate Education In Applied Ocean Science

San Diego
E/G-1

Victor C. Anderson

The fifth and final year of the graduate education project in Applied Ocean Science presents a stabilized ongoing interdepartmental curricular program. The program gained momentum rapidly during the five year period. Enrollments for successive years were two, 11, 23, 34, 36, with 36 projected for the coming year. Out of this group of students five Ph.D.'s have been awarded, two of them in this last year. A projected stabilized level of enrollment of 30 to 40 students is expected to yield four to six Ph.D. degrees per year on an average at steady state.

Broad spectrum of practical courses

The new courses stimulated by this Sea Grant project have provided an expanded base for the AOS curriculum. These courses include the two full-year courses in Acoustics at the undergraduate and graduate levels introduced by Victor Anderson, Douglas Inman's expanded course in inshore processes, a course of Carl Gibson's in turbulent mixing and transport, the two-quarter Methods of Geophysical measurement course organized by George Shor and taugnt collectively by six of the faculty as well as the weekly Applied Ocean Science seminar. Although this latter course, the AOS seminar, is only a one-unit course, it is a key one for the AOS curriculum. It is in this course that the students are exposed to a wide spectrum of the practical aspects of scientific work in the ocean.

New faculty

At least one of the new faculty appointments was strongly influenced by the AOS program. In response to the recommendation of the AOS curricular group, Assistant Professor Clinton Wynant was appointed this year as an addition to the SIO faculty in inshore processes. This field involves the largest number of AOS students of all of the variety of fields represented in the curricular group, probably because it, as a field, has a very direct relevance to our national and global environmental pollution control problem.

Sea Grant Trainee And Intern Program

San Diego
E/G-2

George G. Shor, Jr.

Since the initiation of the first Sea Grant program at the UC-San Diego campus in 1969, graduate students have been heavily involved in the program. During the first year of the UC-San Diego educational program, nine graduate students were appointed under the Sea Grant program; they assisted in setting up the acoustics laboratory and initiated research projects, many of which are now part of the continuing research program of the Sea Grant institutional program. In the second year of the UCSD program, the number of graduate students was increased to 15, in the third year to 22. Additional students were involved in the ongoing programs at UC-Santa Barbara and San Diego State University. In the fourth year, on the university campuses engaged in the program, there were 66 graduate students carrying out research leading toward a master's or doctor's degree with Sea Grant support.

Results of research accomplished by these students are reported under the research project reports with which they were associated.

Marine emphasis university-wide

In developing an educational program in marine resources, we had the option of setting up a large number of new curricula, or instead introducing a marine emphasis in the university-wide educational program by other means. We chose the latter course as a general basic philosophy. The existing Ocean Engineering curriculum at the UC-Berkeley campus was continued and the new Applied Ocean Science curriculum at the UC-San Diego campus developed within the frameworks of existing departments. Here and elsewhere we have chosen as our major educational thrust the introduction of ocean-resource problems into existing cur-

ricula and student research training. In this manner, the flavor of the sea has invaded such diverse departments as Landscape Architecture at UC-Berkeley (coastal planning—project R/CZ-1), Kinesiology at UCLA (recreational resources of LA county coast under project R/CZ-13, Food Technology at Davis (projects R/MP-1, -2, -3), and Applied Physics at UC-San Diego (R/E-2). Students trained in the conventional disciplines within biological, physical and social sciences, and engineering have acquired interest, education and expertise in those portions of their field that can "go to sea," without losing the appropriate training that will make them good civil engineers, geneticists, economists, sociologists, physicists, chemists, or food scientists, wet or dry. In this way we hope to avoid the problem of "oversupply of trained personnel" in specific narrow fields. The nation will need men and women who can apply their experience to the problems of the sea in the future; we hope to continue to produce these men and women.

Ocean Education For the Public

San Diego
E/P-1

Donald Wilkie

Requests by San Diego area schools have created two new educational projects for the Thomas Wayland Aquarium-Museum.

Since bus service for city and county schools is being curtailed by lack of funds and the fuel shortage, designers of a pilot program have asked the aquarium on the campus of the Scripps Institution of Oceanography (UCSD) to cooperate in sending representatives to schools to inform students about ocean life. Docents, trained volunteers, take boxes of "show and tell" examples such as shark's jaws, starfish and puffer fish, and slides for an hour's presentation. Docents pay for their own transportation.

Visual history of SIO

The San Diego County Dept. of Education is also interested in printing and distributing film strips, teachers' workbooks and films on ocean life and ecology. An effort is underway to collect, catalog and make available slides, photographs and films from resources at SIO.

The aquarium's education coordinator administers a comprehensive program for teachers, students and docents. An education program keyed to different grade levels enables teachers to present an oceanography unit to their classes. An ecological symposium for teachers correlates current scientific information about marine resources and research.

Docents from surrounding communities assist classes at the aquarium in learning about marine biology and a program has been organized for selected high school students planning careers in oceanography or marine biology.

More than fifty thousand schoolchildren in organized groups visited the aquarium-museum free of charge in 1972-73.

Undergraduate Training in Marine Technology

San Diego
State University
T/G-1

Glenn A. Flittner

A one-semester undergraduate course in marine technician training has been offered by San Diego State University under the title "Practical Oceanography." Students have been selected for above-average scholastic achievement and basic preparation in the sciences, generally in their junior or senior years. Practical training has been given, both ashore and at sea by the Data Collection and Processing Group of the Scripps Institution of Oceanography.

Thirty-one students have participated in the five regular semester and two special summer semesters of this program since its inception in Spring 1971. Six women and 25 men have participated to date. Undergraduate majors represented were: biology (18); zoology (5); geology (3); chemistry (1); microbiology (1); physics (2); and mechanical engineering (1).

Pre-cruise preparation

The first three to four weeks of each semester are spent in general classes and pre-cruise preparations. More than half of this time is devoted to the taking and processing of data and initial quality-checking when at sea. The remainder of the time is spent on ocean circulation, marine chemistry, water column characteristics and general biology of the proposed cruise regions. Early each semester, students are expected to select a library research topic and to do the work when ashore. At the end of the semester, each student prepares a paper and presents it orally at a scheduled seminar to his peers.

Time at sea has varied from a total of four to ten weeks, depending on vessel sailing schedules. Classes have participated on all or portions of the following research programs: California Cooperative Fisheries Investigations (CalCOFI); North Pacific Study (NORPAX); the Geophysical-Geochemical Section Study (GEOSECS); the Deep Sea Drilling Project (DSDP); and the National Marine Fisheries Service Albacore Tuna Fishery Investigations. Short cruises to the Gulf of California and other special, short-term projects have been included when feasible. All students participated as full working members of the scientific field teams, standing routine watches and meeting station schedules as required. Pre-, mid- and post- cruise data workups were performed. On shore, each student was assigned to a laboratory research project of interest, and special research projects were permitted where possible.

Decisions about careers

All 31 of the students who enrolled in the course indicated at the outset that their purpose was to find career direction. All students, whether or not they remained in the marine sciences after completion, indicated that the internship experience had stimulated one or more decisions toward their careers. Of the 31 students, three have changed direction from their "first love," oceanography, to their second choice: human medicine (2) and veterinary medicine (1). One additional student has elected to go to veterinary school but then to return to do graduate research in marine animal diving physiology. Three of the women have married, one has obtained employment as a laboratory technician, one has changed her major, and one is pursuing a graduate degree in marine zoology.

Students agree a stint at sea is a good way to discover whether or not they are really dedicated to oceanography as a career. Professors at San Diego State have observed that there is "something different" about students who have completed the course: they are generally more mature; they require less guidance and personal attention; they are more imaginative; and they generally excel on examinations. Self-direction and motivation, tried adequately by the sea experience and the rigors of the Scripps Institution of Oceanography intellectual environment, appear to be the key.

RESEARCH

The University of California Sea Grant College Program merges the more measured procedures of basic scientific research with a responsiveness to the calls of government, coastal commissions, citizens' groups, industry and laymen for guidance in designing a judicious plan for living with the aquatic realm.

Coastal zone, nearshore and ecological studies during 1972-73 aided land-use planners by indicating how much pressure the coast can bear from nature and from human incursions.

Though the sea has been a source of nourishment for millenia, new methods are being sought to optimize the yield of fisheries in nature and to develop the scientific base for on-shore cultivation of marine and freshwater species.

Potentially edible substances previously discarded in fish processing are being reconsidered. Scientists are benefitting from observation of societies which have not acquired the wasteful habits of affluence.

Researchers are examining the engineering properties and energy locked in the deeper ocean and ocean floor as well as the power in waves which can be harnessed or tamed to facilitate work, improve survival of ships, crew and equipment during storms or ensure the safety of boats and mariners by calming harbor waters.

COASTAL ZONE STUDIES

The coastal imperative, how to respect the fragile aspect of the sea while recognizing its resiliency, demands and has been receiving a new language and standards for developing those coastal, inshore and nearshore resources that can and should be utilized and for advising decision-makers when and why to let things be.

Before a coherent working model can be adopted, the range of the biological, chemical and physical characteristics of the coastal region and their behavior under varying conditions and degrees of stress must be understood. Social scientists provide indispensable analysis of the legal, political, sociological, and economic impact of decisions about the coastal zone.

Environmental Conflict Identification

**Robert H. Twiss,
Ira M. Heyman, T. G. Dickert,
and Jens Sorensen**

With the passage in 1972 of the "Coastal Initiative" and the creation of a totally new planning and decision-making apparatus for the California coastal zone, the need for expertise in analyzing resource degradation control and conflict in multiple use of the delicate shoreline became critical.

Our involvement with the California Coastal Zone Conservation Commission dates from shortly after the organization of their planning staff in February, 1973. We have dealt primarily with the state-level commission staff in drafting a programmatic outline redefining and clarifying the planning requirements set forth in Proposition 20 (the California Coastal Zone Conservation Act.) The outline was an adjunct to the state commission's own outline and served as a foil for comparing the state's suggested programmatic approach with one from our perspective.

We were asked to review and comment on the outline of the coastal zone plan promulgated by the state CCZCC planning staff. These comments were covered in staff briefings and memoranda.

Position statement

The development of a position statement describing specific issues in coastal zone planning which we felt the plan should attempt to resolve touched upon such issues as:

- encroachment of residential, commercial and industrial development on areas of specialty croplands;
- blockage or degradation of coastal view, particularly from the coastal highway;
- infilling or higher density residential-tourist commercial development in urban-suburban areas;
- removal of existing ranching and dairying uses by residential development;
- pre-emption of rural coastland areas with high potential for recreation by residential-tourist commercial development;
- development of private and public recreation areas and facilities on urban coastal lands;
- development or expansion of marinas or small-boat harbors.

Issue-oriented planning model

Our suggestion for the development of an issue-oriented planning model approach that will help formulate and analyze policies and regulations for the solution of the issues would provide a planning capability to analyze coastal zone issues in terms of five factors:

- capacity of environmental and/or infrastructural systems (definition of "carrying capacity" of resource systems such as watershed/sedimentation budgets, or physical systems capacity, such as highway, sewer and water service systems;)
- conflicts and competition—incompatibility of coastal zone uses, such as pre-emption of agricultural specialty crop lands by residential development, or impacts of marina development on estuarine sanctuary areas;
- compatibility of coastal zone uses—beneficial effects derived from multiple use of location or resources by compatible uses such as coastal ranching and pleasure driving or recreation in nuclear power plant's exclusion zone;
- dependency—evaluation of locational alternatives within the coastal zone, inland alternatives to coastal zone locaiton,and opportunity costs of alternative inland or coastal locations;
- land use mix—specification of facilities and areas (ancillary support) required by coastal zone use and resulting mix of facilities and uses. Determination of the mix of public and private uses for coastal lands and the associated user groups (social mix.)

Providing guidance

Specific types of information and analytic methods were suggested to test and substantiate coastal policies for resolving each of the issues passed. We do not expect our suggested issue-oriented planning model to be adopted directly by the Coastal Zone Commission, but rather hope that the model we suggest will in the middle run provide guidance to the Commission's planning efforts as their necessarily practical approach to planning evolves.

We have prepared a memorandum at the specific request of the state Coastal Zone Commission staff posing socio-economic criteria to be incorporated into the review of proposed projects and planning policies. An

emphasis of coastal planning programs on environmental protection and economic development may fail to give adequate consideration of social equity and social values.

Also at the request of the State Coastal Zone Commission staff, the commissions at the state and regional levels have been provided with a selected set of references and citations to documents pertinent to each of the 12 elements of the adopted outline of the Coastal Zone Plan. These citations were derived from the 1467 entries in our project's coastal zone bibliographic information retrieval system.

The environmental impact identification networks have been refined continually and have been used to assist in the review of projects proposed for the coastal zone.

Planning data bank

We have assembled a small planning data bank for a selected coastal subregion to demonstrate through example the advantages in cost of a sophisticated planning approach that would estimate cumulative effects of coastal development; test implications of proposed policies; and portray alternative futures in graphic and map form. The demonstration area is on the north coast of Santa Cruz County, covering 14 miles of coastline and extending one and one-half miles inland. The data bank is comprised of computer automated maps recorded on 1.4-acre grid cells(10,000 cells in the study area.)

The members of the research team have participated in a number of nationwide and statewide conferences on impact assessment and coastal planning.

Economics of Marine Resources Decision Model

San Diego
R/CZ-2

James J. Sullivan

The original purpose of this study was to develop and implement a management model within which the sum of the effects of decisions of coastal planners and marine resource users on specific marine resources could be assessed. In the first year progress toward the specification and computerization of a land allocation sewerage dischargy model was made. Simultaneously, the difficulty of obtaining usable information on selected marine resources became apparent. The project was then modified and the requested level of support reduced; the main thrust was the development of a comprehensive framework, definitions, tools and methods of analysis with which an integration of such decisions can be modeled and assessed.

Several papers have been published in which concepts, principles, and definitions have been elucidated, a simple simulation model specified, and an example developed. In addition, a bibliography of environmental economics has been developed and a considerable portion annotated.

Physical Criteria For Coastal Planning

Douglas L. Inman

A Shelf and Shore sensor system capable of instrumenting shelf and nearshore waters is gathering simultaneous wave, current and other physical information about the coastal zone near La Jolla. The data are being processed by computer and will be used in specific studies of wave climate, edge waves, canyon and shelf currents, breaking internal waves and other phenomena which could affect coastal development.

Winds, waves, and currents are the principal driving forces for physical processes in the nearshore environment. The understanding of these driving forces and how they interact is presently at a very basic level due to the lack of continuous synoptic data from the nearshore environment. Rational coastal planning can best be achieved by: (1) making systematic and meaningful measurements of significant coastal zone parameters; (2) using these measurements to gain an understanding of specific coastal process; and, (3) develop criteria based on the understanding of these processes that can be used in coastal planning.

Torrey Pines station

A shelf station has been deployed for approximately 10 months off Torrey Pines Beach just north of Scripps, about 900 meters off the beach in 10 meters of water. The station is equipped with four absolute pressure sensors and two accelerometers configured to measure wave climate (i.e., wave energy and direction). A timer housed within the shelf station automatically turns the sensor and transmitting equipment on for one hour four times per day. The data is recorded at the receiving station located in the Shore Processes Laboratory which has acquired about 650 data series of one-hour duration.

Scripps Canyon station

A shelf station has been placed in the head of the south branch of Scripps Canyon at a depth of 18 meters (Figure 1). The station has six instruments which measure pressure, temperature, on-offshore current, longshore current, and tilt angle. Approximately 40 hours of data has been collected from this section.

Scripps Pier

An installation was made at the end of Scripps Pier that consisted of a pressure sensor, an electromagnetic current meter, and a prototype thermistor chain. Interesting temperature structures are observed which at present are believed to be broken internal waves. Approximately four days of data were recorded using this station.

Figure 1. Lower section of shelf station showing anchor assembly and electromagnetic current meter.

Thermal structure outside the surf zone

A preliminary experiment was designed to determine the thermal structure in the nearshore zone using a thermistor chain installed at the end of Scripps Pier. Results show that even in very shallow water (three meters) just outside the surf zone, large temperature changes occur in very short periods of time. An event of this kind, characteristic of those seen, is shown in Figure 2. Such events have been measured at all three shelf station sites. They frequently correlate with intervals of ebbing tide (though such an event does not occur each time there is an ebb tide) and might correspond to breaking internal waves which

are generated in deeper water under tidal influence. A typical event evolves as follows: For several hours prior to the onset of the large thermal front, there is a gradual build-up of warm surface water, depressing the termocline. AS the front passes, a rapid elevation of the thermocline occurs in a period of about one minute. This is followed by a train of smaller fluctuations, the frequency of which is close to the buoyancy frequency of the thermocline layer. The thermocline is then again slowly depressed. Occasionally a large and rapid depression of the thermocline is observed as an independent event and is also followed by a train of smaller amplitude fluctuations.

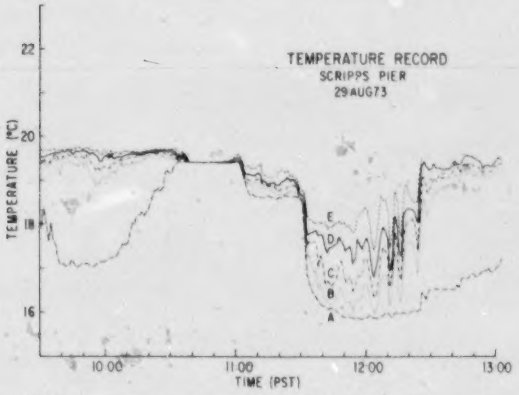


Figure 2. Temperature record at Scripps Pier, bottom (A), 120 cm above bottom (B), 180 cm above bottom (C), 240 cm above bottom (D), 360 cm above bottom (E.)

Electromagnetic current meter

These meters measure two orthogonal components of flow and have been used in two distinct ways. One was to compare the measured horizontal velocities (u and v) produced by surface wave with that computed from the measured pressure field. Figure 3 illustrates the excellent agreement between the pressure and velocity fields for waves in 10 meters of water. There is very close agreement over a wide range of frequencies.

The current meter data (u and v) along with data from a pressure sensor (p) have also been set to compute directional spectra. A comparison of the directional spectra obtained from u, v, and p with that obtained from a four-element linear array has been performed. The two methods give good agreement; however, the u, v, and p method gives less resolution in directional changes than the linear array. More data is being collected to study the effects of differing wave climate.

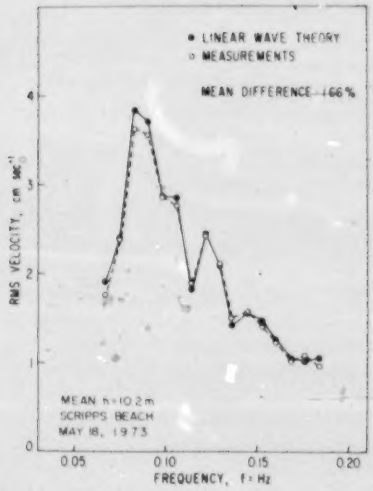


Figure 3. Comparison of measured horizontal orbital velocity with Airy wave theory.

Suspended sediment

During the past six months the optical instrument for measuring suspended sediment has been calibrated in the laboratory. Development has been completed on a support system for using the instrument in the surf zone. The entire set-up has been used off Scripps Pier to measure suspended sediment near the bottom under waves. A pressure sensor was used in conjunction with the sediment meter, so that time series of waves and suspended sediment could be recorded simultaneously. Preliminary analysis of those time series indicates that the peak of the frequency spectrum of the suspension fluctuations is at a much lower frequency than the peak in the wave spectrum, suggesting that it is the higher waves in the group, possibly interacting with other long waves such as edge waves that result in suspension of sediment.

Bottom forms (ripples)

Studies of wave-induced bottom forms (ripples) have proceeded in two areas. First, a dimensionless relation has been achieved for predicting the initiation of grain motion under waves in situations where the grain diameter is less than the thickness of the wave induced boundary layer. The result which is shown in Figure 4 is based on the theoretical considerations of Taylor (1946), and includes field and laboratory data from Scripps as well as data from the literature. The importance of these data is that they describe the lower boundary for bed deformation into ripples.

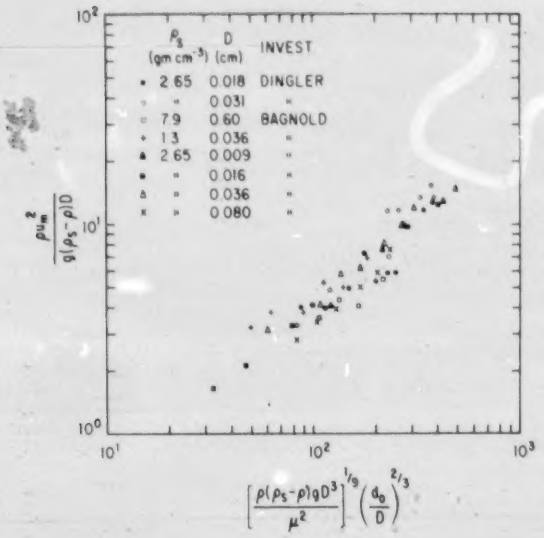


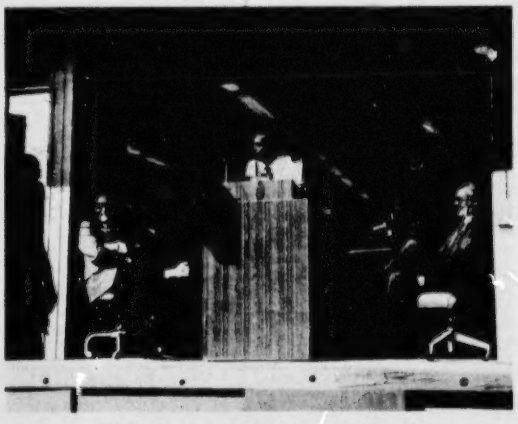
Figure 4. Dimensionless relationship for the initiation of grain motion for the case when the boundary layer thickness is greater than the grain diameter. Values represented by the symbols were obtained under full-scale experiments in the SIO wind-wave channel as part of this study. Other data was taken from Bagnold (1946.)

Second, complete bottom profiles of 190 cm in length are being obtained using high-resolution sonar. Most of the work is being done near the surf zone where the ripples respond to the passage of each wave. Observation shows that the ripples decrease in both wavelength and height with increasing orbital velocity in this region until sheet flow is reached. Through the analysis of detailed bed profiles in conjunction with wave records, it is expected that the relation of wave to ripple parameters in this region will be described. Figure 5 is a typical bed profile taken in 4.3 meters of water depth off the Scripps Pier.

Work is continuing in both the above areas. Data will be collected on grain initiation under conditions where the boundary layer thickness is less than the grain diameter in order to have a complete description of the initiation of grains by waves. Collection of ripple profile data continues with work planned in areas of varying grain sizes.

Disseminating information

Information concerning instruments, techniques and results of research on this project was widely disseminated during the past year. Representatives from the Shore Processes Research Group attended scientific meetings including the Lake Michigan Shoreline Conference Committee Meeting in Chicago, Illinois; Society of Economic Paleontologist and Mineralogist in Anaheim, California; Atomic Energy commission Offshore Power Plant Siting Workshop in Rockville, Maryland; and, the IEEE International Conference on Engineering in the Ocean Environment at Seattle, Washington.



Shore Processes Laboratory dedication.

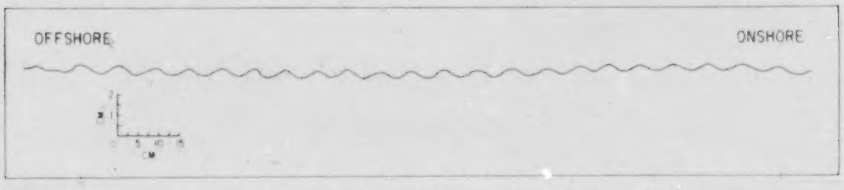


Figure 5. Profile of rippled, fine sand bottom offshore from Scripps Pier in 4.3 meters of water, fall, 1973.

Ecological Studies Of the Near-Shore Zone

**Edward W. Fager and
Paul K. Dayton**

A Japanese seaweed visits the California coast and threatens to alter the association of animals and plants in the area. Young basses and crabs find shelter amid artificial rocks and kelp. One fish community recovers and another tries to adjust to pollution as the site of a sewer outfall is switched.

Proper management of nearshore ecosystems must be based on a functional knowledge of the community organization.

Artificial substrate studies

We have seven artificial "rocks" placed on the sand bottom at a depth of 40 feet. Five are constructed of transite and have been in place 3 to 6 years, and two are of concrete building blocks and have been in place 18 and 4 months.

The concrete block rocks, though 300 m apart, appear to be following a very similar pattern in the development of their epibiota and associated fauna, but one that differs from the transite rocks. The number of crabs, lobsters, and fish, for example, are clearly more abundant at the concrete block structures than at the transite rocks. We believe that to be the result of the greater number and/or smaller size of shelter holes available at the concrete block rocks. In addition, the growth of the attached biota of the concrete structures has been more vigorous than on the transite rocks, with greater numbers and earlier appearances of ascidians, bryozoans, sponges, and algae. This may result from the more rugose surface of the concrete blocks.

Thus the gross structure of the reef seems important in determining the composition of the larger animals which utilize it for shelter. The actual composition of the rocks determines the fine structure which seems to determine the species diversity and respective growth rates of the attached biota.

Artificial (plastic) kelp plants have been established on a trial basis and found to serve as a suitable substratum for several natural epiphytes such as the ectoproct, *Membranipora*, and some of its opisthobranch predators. They have also attracted and apparently sheltered young kelp basses, *Paralabrax clathratus*, and the kelp crab, *Pugettia*.

Nearshore sand community

A large portion of the nearshore benthic environment along southern California consists of a sandy substratum which has a very representative association of animals. Despite the widespread occurrence of this community and the fact that it includes many commercially important species, food web information is very patchy. We are investigating the trophic relationships of the abundant sand starfish, *Astropecten armatus* and *Astropecten californicus*, which are important predators on many components of the epi- and infaunal associates.

We have completed a study of changes in the benthic and associated fish communities surrounding the old and new discharge areas of the Orange County sewer outfall. Sediment quality at the old outfall site rapidly improved following termination of discharge: sulfide and organic concentrations in the surface sediment returned to background levels within months. At the same time, the species and size composition of the benthic community changed radically and approached that of "natural" areas. Community diversity increased and became more equitable, and previously abundant "pollution indicator species" became rare. The species composition of the demersal fish community also changed. During sixteen months of discharge observations at the new outfall area, no significant deviations from predischarge baseline values were observed for any water or sediment quality parameters. Significant changes occurred in the compositions of the benthic and demersal fish communities, however. In general, the abundance of both benthos and fishes increased, the diversity and size of the benthos decreased, and a number of previously rare "pollution indicator species" appeared at high densities. At both impact and recovery areas, rates of change were greatest (and most change was completed) during the first twelve months after the switch event.

Kelp community studies

Projects dealing with the ecology of the southern California kelp community are continuing, and have produced some important results. During the past two decades the kelp population and its complex association of species, has disappeared from some parts of the California coastal zone, has declined markedly in most other areas, and recovered nicely in a few areas. Maintenance of the kelp community is vital to commercial kelp harvesting and abalone and lobster fisheries, as well as a large recreational industry.

Throughout our baseline research, the primary source of mortality of adult *Macrocystis* plants appears to have been entanglement by drift plants initially torn free by heavy storm surge. This results in a "snowball" entanglement effect which can produce large clearings in the kelp canopy. Mortality due to biological activity such as sea urchin grazing is, by comparison, of marginal significance in our study areas.

Studies of the ecological consequences of the release of large quantities of quicklime into the kelp community are continuing. Many tons of quicklime have been spread over kelp beds by commercial kelp harvesters in an effort to reduce populations of sea urchins, particularly *Strongylocentrotus purpuratus* and *S. franciscanus*. In the past, such operations have aided the recovery of the kelp bed at Pt. Loma. However, quicklime is known to kill other invertebrates, especially other echinoderms, and may be toxic to many other members of the kelp community. This could be important as several asteroid species are predators of the urchins and act as a natural defense of the kelp community algae against urchin grazing. The two quickliming operations we have observed did not result in as much obvious damage as had been feared previously, and in fact, only a few species seemed affected. However, four species did suffer heavy mortality as a direct result to quickliming. These are the urchins *S. purpuratus* and *S. franciscanus*, the primary target of the quicklime operations,and the holothurian *Parastichopus parvimensis* and the asteroid *Pisaster giganteus*, species whose roles in maintaining the natural structure of the kelp community are unknown.

La Jolla-San Diego Underwater Preserve

A biological monitoring program has been instituted in the La Jolla-San Diego Underwater Preserve at Devil's Slide, and its adjacent rocky intertidal area. Initially, the objectives were to count fishes, lobsters (*Panulirus interruptus*), abalones (*Haliotis* spp.), and other species subject to sport and commercial exploitation prior to the establishment of the park preserve in 1971. The program has been expanded to deal with prominent plants and animals, with the goal of obtaining baseline information and determining the effects of protection from commercial removal and casual collecting on the biology of the area. In addition, quantitative comparisons are now being made between the Devil's Slide area and the Bird Rock area, a nearby rocky intertidal zone physically and biologically similar to Devil's Slide, but outside the protection of the underwater preserve.

The ecology of *Sargassum muticum*

The introduction of this Japanese seaweed has caused much concern among biologists along the Pacific Coast. In British Columbia and Washington, the region of the first introduction in the 1940's, large areas of the intertidal and shallow subtidal are now diminated by this species. The discovery of *Sargassum* in Great Britain during the past year has led to an extensive eradication program, spurred primarily by the concern expressed toward this algae in the Pacific Northwest. An analogous situation exists on the East Coast where *Codium fragile*, a native Pacific algal species, has become a pest in the bay areas of New England. *Sargassum muticum* is a relatively new addition to the flora of Southern California but it has established large populations in protected waters near Catalina Island and in bays from Newport south into Baja California. The problems associated with this alga in Southern California have been restricted to the recreational use of the bays, especially the marinas. At the present time, however, populations are becoming well established at outer coast locations where they are interacting with native plants and animals. Unlike the bay regions of Southern California, which lack a well developed assemblage of rock dwelling species, the outer coast intertidal region offers *Sargassum* the opportunity to greatly alter the association of plants and animals of this area.

During the past year populations of *Sargassum* were monitored in Mission Bay and at two outer coast locations, Bird Rock and the La Jolla Ecological Preserve. On request of Mission Bay Associates a complete survey of this algae was conducted in Mission Bay. This request was generated primarily by the complaints of various marina

operators who had the problem of *Sargassum* blocking nearshore boat slips and fouling propellers and water intakes. There was some concern that this algae would spread into the open areas of the bay where it would interfere with boating activities. The results of the survey showed that the population of *Sargassum* has probably reached its peak development since all the available substratum along the shoreline is now occupied. In addition, the problems are restricted to the months of March through June due to the very seasonal growth of this algae. For these reasons no extensive removal program could be suggested other than hand clearing of the affected areas when growth became excessive.

An extensive quantitative study is underway in the open coast situations in order to asses the effects of *Sargassum* on the other species of plants. Baseline transects for *Sargassum* densities showed a great increase in the number of plants during the spring to fall, 1973. The most dramatic increase was from 9 to 73 plants in a ½m^2 quadrat. A large number of experimental clearings were made to determine the fate of newly opened substrate in the intertidal; *Sargassum* occupied from 80-100% of the substratum in these clearings in the fall, 1973. This complete dominance in newly cleared areas appears to be a primary mechanism by which Sargassum can outcompete other species in the intertidal zone. This would be especially true in competition with Phyllospadix, which seems primarily to depend on vegetative growth to increase its population, and has showed very little ability to colonize new areas.

Ecology of Santa Cruz And San Mateo County

Santa Cruz
R/CZ-8

William T. Doyle and
John S. Pearse

The purpose of this study was to establish the diversity and distribution of intertidal plants and animals of the intertidal rocky platforms along the southern San Mateo and Santa Cruz county coast. The data obtained provide an inventory of what is currently present along our coastal section and serve as valuable reference point information in order to assess the magnitude of future changes.

At the time this study was begun (Fall, 1971) great changes in coastal land use were planned for this region. This region already served as the major coastal recreational outlet for the entire central California region. Adjacent to the city of Santa Cruz, a planned housing development that would nearly double the size of the city was envisioned. A trailer park on the bluff overlooking the coast was planned for southern San Mateo County. A nuclear power plant was planned for siting north of the Santa Cruz County town of Davenport. In addition, ocean and bay sewage discharge pattern changes were being dictated by the State Regional Water Quality Control Board.

An extensive inventory of the intertidal marine biota along this coastal section seemed critically needed at this time. In addition, the Association of Monterey Bay Area Governments (AMBAG) was to begin a one-year oceanographic study of Monterey Bay, and this study would complement and augment that study by extending the intertidal portion of their project out onto the open coast.

Sub-tidal kelp forests

In addition, during 1972-1973 a study of sub-tidal kelp forest ecology was begun at three selected sites, one each in Monterey, Santa Cruz and San Mateo Counties. Sub-tidal kelp forests also can be expected to change considerably in the near future. Not only will the continuing urbanization change the kelp forest environment through increased sewerage discharge and terrestrial run-off into coastal waters, but plans are being formed to harvest kelp along the central California coastline. Moreover, the sea otter population has been expanding along our coastline, and by feeding on a wide range of food items, they may both increase kelp forest diversity and productivity, and lower the numbers of some shellfish to numbers which cannot support human fishery activity. We sought to acquire fundamental information to help develop wise management programs of the central California kelp forest communities, including sea otters in these communities. Our three study sites included one (Monterey)

with an established sea otter population, a second (Santa Cruz) where establishment of such a population seems imminent, and where human activities have been extensive, and a third (San Mateo) where both sea otter and human activities have been minimal.

The field portion of the intertidal study was completed, as scheduled, during 1972-73. A total of 10 sites were studied quarterly for most of the two-year period. At each site, the seasonal abundance and distribution was studied by use of permanent quadrats, from which quantitative data was derived, and by a thorough biotic survey of each entire study area. The sites chosen for intensive study were selected because they appeared to be situated adjacent to areas projected for major land use changes. For example, sites were studied on both sides of the site projected for the nuclear power plant. The ten sites selected are: 1) Pigeon Point (north side), 2) Pigeon Point (south side), 3) Año Nuevo Point, 4) Año Nuevo Cove, 5) Scotts Creek, 6) Davenport Landing, 7) UCSC intertidal area adjacent to Natural Bridges Beach State Park, 8) Almar Street inshore from the City of Santa Cruz sewer outfall, 9) Santa Cruz point, and 10) Soquel Point near the county's sewer outfall.

Permanent collection

At each site, and for each quarter of study, a voucher specimen of each plant and animal type encountered was selected and was carefully curated. These organisms have been placed in a permanent research-reference collection. During the summer of 1973 and continuing 1973-74, the identifications of all these organisms are being checked prior to the publication of any results. The more than 400 species of animals and 200 species of plants found are being catalogued on cumputer cards for print out and analyses. Preliminary lists, however, have been requested and provided to AMBAG, State Department of Parks and Recreation, and San Mateo County.

Field studies completed

In addition to the above sites, six additional sites were studied at least once. These sites were chosen, at least in part, in order to fill in the geographic gaps in the more extensive studied areas described above. Sites studied included: 1) Franklin Point, 2) Waddell Creek, 3) El Jarro Point, 4) Baldwin Creek, 5) Santa Cruz Point West, and 6) 41st Avenue. Only the biotic diversity of each site was sampled; no permanent quadrats were established. Again, voucher specimens of each biotic type were obtained and added to the UCSC collection.

In order to establish a research reference site out of Monterey Bay and away from the Monterey Bay-San Francisco Bay influence region, we selected a small intertidal shelf just south of Mill Creek, Monterey County, for study. The biotic diversity of this site was studied in 1971-72 and once during 1972-73. Voucher specimens were taken.

During 1972-73, a random quadrat procedure was used to check biotic diversity and distribution at three of the sites named above: 1) the UCSC site at Natural Bridges, 2) Soquel Point, and 3) 41st Avenue. The results from this sampling will be compared to those obtained from the permanent quadrat method.

Potential algal resource

The standing crop biomass of *Iridaea splendens*, a carrageeninophyte of potential economic importance in this coastal area, was studied at most of the intensive study sites during the past two years. A modified random quadrat method was used and either 1) the entire quadrat area was scraped clean or 2) all blades greater than 1 cm were harvested. In the laboratory the blades were sorted into reproductive stages and size classes, and fresh and dry weight measurements were obtained. Surface sea-water temperature and water samples (subsequently frozen) were collected at the same time the *Iridaea* was being collected. A Technician auto-analyzer, now installed, will be used to analyze the sea water samples (e.g., for phosphate and nitrogen species). The *Iridaea splendens* biomass data and sea-water sample data will be analyzed during 1973-74.

Hopkins Marine Life Refuge

Most of the sub-tital work focused on the kelp forest in the Hopkins Marine life Refuge at Point Cabrillo, Monterey County, where resident sea otters occur. An inventory of most of the animal and plant species found in the area has been completed and voucher specimens are in our reference collections. Quantitative studies provide density estimates of some of the major plants and animals in this kelp forest, including kelp, snails, abalones, sea urchins and sea stars. Overall, we found this kelp forest community to be both rich and diverse. Similar quantitative studies were done in the summer off Santa Cruz Point, Santa Cruz County, and Año Nuevo Island, San Mateo

County. Santa Cruz Point has been a popular diving locality for many years, and we found much of the area to be dominated by large numbers of sea urchins and relatively barren of algae; very few abalone were found. Año Nuevo Island is relatively inaccessible and there has been little human or sea otter activity in the area. We found both sea urchins and abalones to be numerous, but overall species richness and diversity appeared to be relatively low. These studies provide information both for comparison between contrasting sites, and, more importantly, for following temporal changes as human activities and sea otter populations change.

Natural Oil Seepage In the Santa Barbara Channel: Physicochemical Aspects

Santa Barbara
R/CZ-9

Paul G. Mikolaj

What are the chemical, physical and environmental parameters which promote or prevent shoreline contamination from natural oil seeps in the Santa Barbara Channel? What happens to oil during and after its release from the sea floor? For four years, researchers conducted aerial and surface studies of floating oil slicks, surveys of affected beaches and the coastal zone, underwater exploration, mapping, and sample collection in the vicinity of Coal Oil Point.

The initial effort in this project was devoted to an investigation of coastline contamination by oil and tar deposits. Studies conducted 10 years previously had shown that most of these tar deposits have their origin in offshore natural oil seeps. However, these studies were not able to pinpoint the exact seepage locations that were the major offenders. Further complicating the picture of beach contamination and identification of their source was residual oil leakage from the blowout at Union Oil Company's Platform A.

Field programs offshore

Since the Coal Oil Point natural seeps were determined as being the major source of oily pollutants throughout the entire Santa Barbara Channel coastline, a major effort was then undertaken to study their in situ behavior. This effort, which began in the fall of 1970 and continued through early 1973, was concentrated on one of the smaller seepage zones commonly known as the Isla Vista seep. This seep lies just outside the kelp beds in 18-20 m of water, and is about 900 m offshore. Its relatively small size and isolation from other seepage zones made it an ideal outdoor laboratory.

Results of the seafloor mapping showed that the seepage zone covered an area of 10,000 to 20,000 m^2. Numerous measurements of the flow rate from this seep indicated that the average amount of oil being released was on the order of 2000 l per day. Thus the seep could be pictured as one oil globule being released per minute per about 10 m^2 of the seafloor. The oil seepage rate, however, was found to vary considerably. Based on a year-long series of measurements, the principal factor in this variation was determined to be tide height. The results indicated that a 4-ft tidal range causes the oil seepage rate to vary by a factor of 2.

The background and experience gained in analyzing these natural seep oils came into valuable use in June, 1973, when a new subsurface eruption of oil and gas was reported about 2 miles offshore from Coal Oil Point. Working in conjunction with state, federal, and oil industry officials, a detailed analysis of the oil from this new upwelling showed it to be significantly different from nearshore natural seep oil, and also to be different from oils then being produced from State tideland leases.

Analysis and modeling program

As results of the field programs and laboratory work became available, efforts were devoted to correlating the data and integrating the findings. Although this data analysis program was usually straightforward, it was occasionally necessary to break new ground or modify existing concepts.

In the process of statistically analyzing beach tar data to establish likely sources, we became aware of a correlating model that appeared to have considerable potential in the reduction and interpretation of environmental pollution data. This model was the Weibull distribution function, which is an empirical 3-parameter function that previously had been applied to a variety of other topics. The Weibull function was therefore

used to analyze a variety of oil pollution data such as spill size, spill duration, and coastline contamination. In each case, the Weibull method offered new insight into the interpretation of these data. Its extension to other forms of environmental pollution measurements appears to be quite promising.

Theses Completed

Chapin, D. W., 1972; M.S. Thesis, "Source Identification of Tar Deposits from the Santa Barbara Channel Coastline"

Delaney, R. C., 1972; M.S. Thesis, "Trace Metal Weathering Effects and Characterization of Oil from Natural Seepage in the Santa Barbara Channel"

Sivadier, H. O., 1972; M.S. Thesis, "Experimental Measurement of Evaporation from an Oil Slick on the Open Sea"

Cooperating Organizations

Santa Barbara City College
University of Southern California, Allen Hancock Foundation
University of California, Irvine
Union Oil Company of California
Standard Oil Company of California
Gulf General Atomic Corporation
Clean Seas, Inc.
Atlantic Richfield Oil Company
General Research Corporation
Marconsult, Inc.

Sea Coast Planning Project

Carl C. Hetrick

Santa Barbara
R/CZ-11

We undertook to enumerate and measure the direct and indirect economic impacts of specific environmental uses (e.g., land use developments) on the five northern Channel Islands—Santa Barbara, Anacapa, Santa Cruz, Santa Rosa and San Miguel Islands off the coast of Southern California—to determine and allocate the appropriate economic costs and benefits of the proposed alternate environmental uses.

We carried out cost analysis and estimated demand for a National Park alternative, projecting numbers of visitors based on population and income figures over a period of several decades. No conclusive statement could be made. The analysis and results of projections were submitted in the form of a sixty-page paper to the Marine Science Institute in August, 1973.

Sea Coast Planning Project: Santa Barbara Channel Islands

James J. Sullivan

A study of transportation concluded the Islands do meet a recreational need but are not now a major recreational area due to costs of transportation and difficult access. Mainland areas have easier accessibility at much lower cost; however, Channel Islands use is icreasing as Southern California expands.

A third study focused on Santa Cruz Island which has a Field Research Station administered by UC-Santa Barbara by virtue of a ten-year license agreement between the University Regents (under the auspices of the UC Land and Water Reserve System) and Dr. Carey Stanton, major stockholder of the Santa Cruz Island Company. The Reserve System ensures long-term research and should be a future source of funds for the operation of the Field Station.

Sea Coast Planning Project: Public Policy and the California South Coast's Tourist and Retirement Industries: Political Economy of Coastal Zone Resource Use

W. Elliot Brownlee, Lloyd Mercer, and W. Douglas Morgan

Model for measuring impact

We have developed and applied to the Santa Barbara coastal zone a simple model for estimating the impact of the differential rate structures of local taxing agencies on the allocation of capital among various uses and local subregions, concluding that Santa Barbara's shift of tax policy in the 1960's may well have not only discouraged oil-related activities but discouraged the continued growth of the tourist industries. Further, we continued development of a simulation model for the determination of optimal

land-use patterns for a coastal zone: defining the basic relationships among benefits of land use, population growth, and externalities of alternative land use and analyzing simulated solutions for a set of hypothetical coastal zone economies. Finally, we expanded an continued a long-term project of exploring the patterns of criteria applied to planning for resource use in Santa Barbara County, primarily since the 1920's—a project that has suggested a strong, deep-seated historic opposition to "no-growth" policy choices.

Manuscript prepared

An article manuscript entitled "Politics, the Environment and the Coastal Zone" was also prepared. This manuscript is now in rough-draft form and undergoing revision, and has been accepted for publication by *The Journal of Coastal Zone Management*.

An abbreviated version of this manuscript is also scheduled to appear in the *Coastal Zone Handbook* to be published by the Conservation Foundation. The topics covered in this article are generally similar to those covered in the aforementioned report. The difference between the two documents is that the first is completely descriptive, while the second is more narrative and analytical.

Sponsored colloquium

The project's third principal activity for the year was the sponsorship of a colloquium series entitled "Politics, Economics, and the Coastal Zone." The format for this colloquium series was that on each of five consecutive weeks a visiting researcher knowledgeable in coastal zone matters was brought to the campus for the purpose of presenting a paper on a selected aspect of Coastal Zone management. The visitor was then available for the remainder of that day and for one additional day to consult with faculty, students, and interested members of the public. A joint wrap-up session was held at the end of the colloquium series at which all of the speakers were present for an overview of the material which had previously been covered. The attendance at the colloquium series averaged between 20 and 30 persons.

Sea Coast Planning Project: An Analysis of the Impact of Beach Pollution on the Development of the Channel Coastline with Particular Reference to Natural Oil Seeps

Carl C. Hetrick, Paul G. Mikolaj, and W. Douglas Morgan

A report entitled "The Santa Barbara County Coastal Zone and Environmental Policy Survey: Item Response Summary" was prepared and widely distributed not only to the Santa Barbara County Planning Department but to such other interested agencies as the South Central Coast Regional Commission, the Santa Barbara City Department of Recreation, the County Parks Department, and the State Department of Fish and Game, and the State Department of Parks and Recreation.

Study deals with issues

The study deals with such issues as oil drilling in the Santa Barbara Channel, recreational use of the County's beaches, intensity of coastal development, alternate future uses for the Santa Barbara Channel Islands, as well as specific evaluations of representative large-scale developments. The report also touched on such other issues as population policy, air pollution, and industrial development. The material for the report is now being integrated into the coastal development plan which is being prepared by the South Central Coast Regional Commission.

Sea Coast Planning Project: Impact of Offshore Oil Production on Santa Barbara County

Robert Deacon

Fear another spill

A preliminary study indicated that development of offshore oil and gas reserves generates substantial local income primarily in the form of wages for those persons directly employed by the industry and tax revenue to finance government services for the public at large. Despite this, there is significant local opposition to coastal development in general and offshore operations, and the possibility of another oil spill, in particular. Such opposition would indicate that for at least part of the population, the potential environmental modifications which accompany such activities are not worth the economic benefit which coastal development bestows. Tidelands and offshore waters are a public resource and should presumably, be managed in the public interest. However, the public interest, or the values which individuals attach to commonly held resources are difficult to percieve.

Benefit or obstacle?

The public decision chosen for analysis was the "Coastal Zone Conservation Act" (Proposition 20) an initiative measure offered to the voters of California in November, 1972. This particular measure provided an ideal vehicle for examination of public preferences toward coastal land use. Proposition 20 established commissions to develop a plan to promote the "preservation, protection, restoration, and enhancement of [the] ecology of [the) coastal zone." It also created a "Permit area...between the seaward limit of state jurisdiction and 1000 yards landward from the mean high tide line...[and prohibited] any development within the permit area without permit by state or regional commissions." The issues in this case were rather clearly drawn. Proponents of the measure argued that it would benefit the public by enhancing the quality of the natural coastal environment and promoting public access. Opponents emphasized the potential costs, warning that it would impose a virtual moratorium on building in the coastal zone, reduce property values, erode local property tax bases and create severe unemployment in the construction industry.

The preliminary research completed to date allows only general statements about patterns of demand for undeveloped coastline. More accurate measurement of demands and the distribution of benefits among various segments of society awaits further research effort.

Sea Coast Planning Project: Beach Survey

John A. Sonquist
David Gold

Patterns of beach use

A survey of beach users was conducted on four Santa Barbara city beaches and the grassy areas adjacent to them between July 31, 1972, and August 27, 1972. The total number of respondents sampled was 623, although only 572 interviews resulted in sufficiently complete questionnaires for purposes of analysis. Those who refused to be interviewed did not have characteristics that differed significantly from the general sample, so there appears to be no systematic biasing effect on this account.

Racial minorities were markedly underrepresented in the sample of beach users. The proportion of non-whites in the Santa Barbara area is more than three times that found on the beaches. Furthermore, the patterns of beach use by non-whites differed distinctly from that of whites. They tended to be found more frequently in the grassy areas somewhat farther from the ocean rather than on the sand or in the water and were less likely to be sunbathing.

Senior citizens were not found to be frequent beach users, researchers hypothesized, because older persons were not as likely to own or drive automobiles, the usual means of reaching beach areas.

Most beach users engaged in physical activity relating to the ocean. Only one in five

questioned had not come to the beach to use the ocean.

Social event

Beach use may definitely be viewed as a social event. Over half of those interviewed came with one or more persons. Many people brought children to the beach; while married people were more apt to go to the beaches with family members, singles went to the beaches with a friend or small group of acquaintances. Beach use is thus a very significant social activity that people do together. Asked to state their "second choice" of recreation activity if the beach they were attending was closed, many indicated that they would look for another beach area.

Monitoring of Pollution Parameters In San Francisco Bay

Berkeley
R/CZ-12

Pat Wilde, Ugo Conti, and H. Frank Morrison

The complexity and cost of most chemical and biological analyses of water quality implies the use of a small number of fixed monitoring stations and a low-frequency sampling program, raising doubts whether the data are representative of the body of water under study. This problem is particularly acute in estuarine waters where environmental conditions change rapidly with tides currents, fresh water runoff, etc.

At the University of California Richmond Field Station, a pumping station has been installed to provide San Francisco Bay water to a system of tanks which are part of a toxicity study sponsored by the State of California Water Resources Control Board (SCWRCB.) In order to establish how the water supplied by this system is representative of the Central San Francisco Bay, two series of environmental monitoring surveys were conducted with a towed underwater monitoring system.

Picture of parameters

This produces a "picture" or map of several water quality parameters. The maps may then be used to position a proposed fixed station or to extablish if and how an existing station is characteristic of a certain body of water.

The data collected during this work would indicate that the supply station is located in an area of relatively poor circulation and would have been more effective if located approximately one thousand yards to the southwest of its present position.

Recreational Resources Of Los Angeles County Coast

Los Angeles
R/CZ-13

Glen H. Egstrom

The development of baseline data on the nearshore underwater resources of Los Angeles County are fundamental to the intelligent planning for the use of these resources. The present project is developing an inventory on a priority basis to aid the Los Angeles County Department of Beaches in its efforts to develop an environmentally sensitive program of recreational use of the nearshore area in conjunction with on-shore facilities and services.

The Los Angeles County Coastline has become a highly sensitive issue during the past few years. The County Department of Beaches and its advisory committee have begun establishing priorities for the acquisition and development of public recreational areas and accessways. These developments require insight about the state of the resource both above and below water if intelligent decisions are to be made. The stated purpose of this project is to develop a recreational resource inventory of the Los Angeles County Coastline from the water's edge to 500 yards out to sea with some selected inventories in water out to 60' in depth.

Bottom phenomena

The study examines the topography, ecology, and geologic phenomena on transect lines which are run from the beach at regular intervals (500' ±) along the coastline in areas which have previously been assigned priorities for development. Over 100 such transects have Nicholas Canyon, Broad, Zoma, Escondio, Corral, West Malibu, Big Rock, Las Tunas, Topanga, Sunset, Redondo, Torrance, and Malaga Cove Beaches. The inventories are accompanied by aerial photo and map data supplied by various agencies including the Department of Beaches and the County Oceanographer. An additional working relationship has developed between the USC Sea Grant project and the UCLA project. A graduate student in Geology at USC has joined our group to provide better insight into the geologic parameters of the inventory. Teams are also working from a private 60' research vessel, the Piedra Verde, and are taking video tape recordings of the bottom environment when conditions are favorable.

Los Angeles County Department of Beaches personnel have worked in close cooperation with the UCLA group and have benefited the program greatly. The close working relationship between the Los Angeles County Department of Beaches and UCLA has greatly simplified our work.

L.A. beach survey

Project divers' syllabus

A project divers' syllabus was also developed and issued to all participating personnel.

Current efforts include participation in the development of plans for an underwater reserve area in the Palas Verdes area and the establishment of baseline data for a new state park in the Topanga area.

The importance of the resource evaluation has been appreciated by several county agencies and some community groups during the past few months. Most of the inquiries have been concerned with the extent of biota in areas where beach developments are being planned, especially in areas where beach stabilization programs are under study.

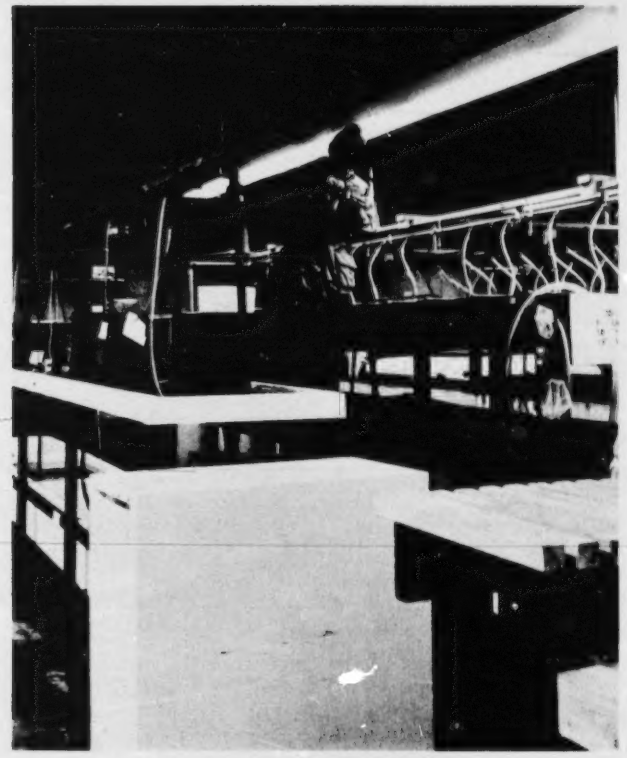
Parks and preserves

The inventory to date lists a number of areas which are well suited to development as parks, preserves and limited use. There is a nearly continuous shallow reef (25-30') area at the extremes of the county area, and it is exposed for part of the year over nearly all of the sand beaches in the center of the Santa Monica bay. The sand migration covers the reef in the bay at other times. The forms of marine life of interest to underwater recreationists are relatively sparse except at the extremes of the county where private property on the beach is extensive. Much of the difference appears to be the result of sand migration covering to outcroppings.

The second half of the project will progress at a faster rate, since most of the literature survey and training problems are now taken care of.

Cooperating Organizations

Los Angeles County Department of Beaches
Los Angeles County Engineer
Leonard Greenstone Co.
Los Angeles County Sanitation District
California Fish and Game
Southern California Coastal Water Research Project
University of Southern California Sea Grant



FISHERIES AND AQUACULTURE

If the domestication and mass rearing of marine animals is to make inroads into the food needs of the human race, it is essential that experiments progress far beyond the culture of luxury food such as lobster. Also, there must be discovered inexpensive food sources that marine animals can utilize more effectively than can the present, highly efficient cultured animals such as chickens and cattle.

There is work to be done in improving methods of evaluating and harvesting underutilized resources such as algae, working with advisory personnel to develop better marketing techniques and consumer education; replenishing stocks of plants and animals which have been overfished or overharvested; making more prudent use and careful study of matter now discarded as waste which might be used in creating new edible products; and improving familiar foods from the sea. By this variety of routes, researchers may arrive at a way to establish the foundation for commercial cultivation of many marine species.

Uses of Waste in Aquaculture

Robert C. Cooper and Robert W. Holmes
Adrian M. Wenner and Floyd A. DeWitt, Jr.
Berkeley, Santa Barbara
R/FA-1

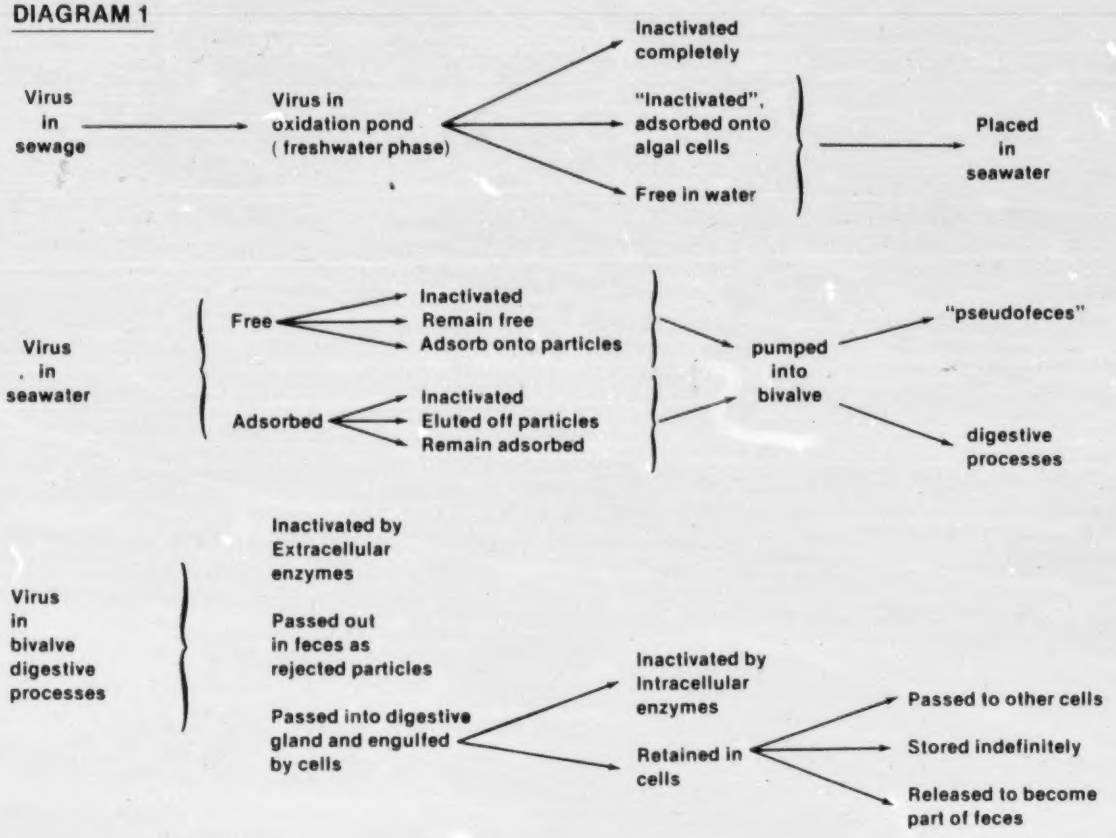
The development of a scheme to integrate wastewater treatment with mariculture often yields control over one or the other process but not both. Two major problems of such an integrated system are ensuring public health and finding appropriate commercial uses for the sewage-grown algae.

Progress to date has shown the feasibility of undertaking the maintaining of 300 mussels, *Mytilus edulis*, for several months on a diet consisting exclusively of sewage-grown algae (primarily *Euglena* sp.) To our knowledge, no mariculture system has been operated on the basis of sewage-grown, freshwater algae as the primary nutrient source. Further development of this potential will be conducted on a larger scale during the coming months.

Public health hazards

Our major effort during the past year has been to develop methods for the evaluation of public health hazards, with particular reference to viral agents, which would be involved in puting into operation a human waste-associated mariculture system. Since it has been shown by Sobsey that viruses adsorb to sewage-grown algal cells, it is most likely that viruses will be carried from step to step within the mariculture system. Diagram 1 indicates the possible outcomes of viral involvement in a sewage-algae-mollusc mariculture system. The investigators are preparing to quantitate viral presence at four major points within the mariculture system. Virus levels are being determined initially in primary treated (settled) domestic sewage effluent entering the ¼ scale bacterial-algal oxidation pond system located at the University of California's Richmond Field Station. The number of viruses adsorbing to pond algae and the effects of seawater and molluscan digestive processes upon their survival will be assessed.

DIAGRAM 1



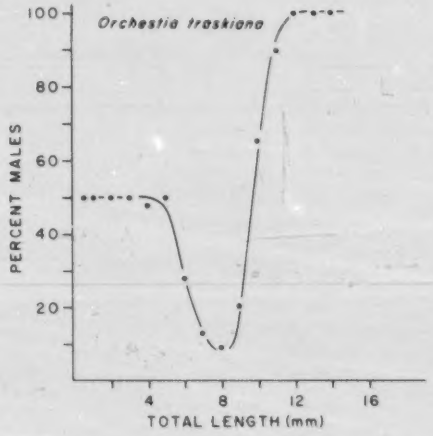
The successful production of amphipods (beach hoppers) such as the ubiquitous and hardy *Orchestia traskiana*, nourished on sewage sludge, liquid sewage effluent or drift seaweed, could provide food for marine and aquarium fish, shrimp culturing and bait for sale in sporting goods stores.

Selective breeding

Animals collected and compared from eleven different mainland and island habitats in the Santa Barbara area indicate that representatives from one population or another can survive in almost any microhabitat, barring desiccation. Studies are now underway to selectively breed strains more tolerant of desiccation with a larger maximum size and a faster growth rate.

In feeding and growth experiments, freshly caught cobblehoppers seemed to survive best on a diet containing some seaweed. Cobblehoppers were freeze-dried and tested as pet fish food and were used as live bait.

A simple outdoor algal culture system was constructed which permits the simultaneous culture in different containers of planktonic algae and attached micro-algae (periphyton) on a primary treated sewage and seawater mixture. The algae produced on the substrates will be used as food for juvenile abalone. The planktonic algae currently produced by the system have been used as food for *Mytilus edulis* which, in one experiment, grew nearly as fast as a control natural population.



Rearing of Larval Marine Fishes

San Diego
R/FA-2

Reuben H. Lasker

Marine biologists have turned a drawback for aquaculturists—the fragility of early larval marine fishes—into an advantage by using the delicate young fishes as indicators of environmental changes and dysfunctions. Methods have been developed to mature and spawn a variety of marine fish in captivity to provide larvae for these experiments. A cooperative project has extended its expertise in analysis to studies of the effects of DDT accumulated from food on reproduction and ability to withstand temperature reductions in the gulf croaker and the northern anchovy. According to a student report, larval anchovies during early development expend almost all of their energy in swimming.

Four species of marine fish, the northern anchovy, *Engraulis mordax*; the Pacific sardine, *Sardinops caeruleus*; the Pacific mackerel, *Scomber japonicus*; the croaker, *Bairdiella icistia* and the anadromous striped bass, *Morone saxatilis*, have been brought to sexual maturity under laboratory conditions with techniques developed in this Sea Grant project. All of these fish have been matured during a time period differing from their natural spawning season. Spawning has been induced in all but the striped bass which, at this writing, has yet to respond to hormone injections despite the obvious maturation of the gonads. Anchovies have been established in the Southwest Fisheries Center Aquarium which provide fertilized eggs every day throughout the year, in contrast to the seasonal spawning of this fish in the sea. Thus far all of the other fishes have required hormone injections for hydration and release of eggs although Pacific mackerel (and yellowtail, *Seriola dorsalis*) have spawned spontaneously during their spawning season in outdoor tanks. We believe therefore it may be possible to have spontaneous spawning in the SWFC Aquarium of Pacific mackerel under the proper environmental conditions.

Speeding up spawning

Each species, depending on its normal spawning time in nature, is given a constant day and night period every 24 hours. By manipulation of temperature and with heavy feeding, maturation of the gonads proceeds. Spawning is usually induced where neces-

sary by injections of human chorionic gonadotrophins, gonadotrophins from pregnant mare serum, or extracts of salmon pituitaries.

During this project, representatives from the California Department of Fish and Game participated with us in a salinity effects study of striped bass eggs and larvae. We found that fertilized eggs will tolerate 5% sea water and the hatched larvae can be acclimated to full sea water gradually over eighteen days. Growth is very rapid for the young larvae in sea water and metamorphosis is achieved by 33 days at 19°C. These results imply that there is a possibility of establishing sea water hatcheries for this desirable sport fish.

Testing diets

With the larval anchovy as the test organism, Dr. Douglas Conklin worked for a year testing a variety of prepared foods. During the course of the work, some of the diets were tested also with striped bass larvae and Pacific mackerel larvae. Dr. Conklin designed a culture tank and water flow system for testing these diets and R. Mindlin encapsulated a variety of diets in gelatin and gum acacia for testing. No single diet was adequate for anchovy larvae, but the important fact was established that first feeding anchovy and other larvae will ingest non-living particles. Striped bass larvae grow on a prepared diet without living good but we have never achieved the growth rates typical of these animals when fed cultured food organisms *ad libidum*. A paper entitled, "The Development of Artificial Diets for Larval Marine Fish," by Dr. Conlkin has been prepared for publication.

Other laboratories report

Cultures of the dinoflagellate *Gymnodinium splendens* and the rotifer *Brachionus plicatilis* have been sent to over 25 laboratories involved in fish and invertebrate culture work for establishing their own cultures to feed larval fish and invertebrates. Prepared microencapsulated larval fish foods have similarly been disseminated. Reports from some of the laboratories (e.g., Shleser, UC-Davis), indicate that for some invertebrate larvae the diets prepared here are eaten and can induce rapid growth.

Rearing of anchovies through metamorphosis has never been wholly soccessful using prepared or cultured foods. However, Pacific mackerel and striped bass have been successfully brought through metamorphosis on cultured organisms; striped bass ate and thrived on *Artemia* before conversion to commercial troutfood. *Artemia* has never proven successful with other species studied here.

Effects of DDT from food

Experiments were carried out with the gulf croaker and the northern anchovy to examing the effects of DDT accumulated from food on some aspects of reproduction, and on the ability of the fish to withstand severe reductions in temperature. In all cases DDT was incorporated in the daily food ration at specified levels. Gulf croakers were spawned every few weeks for four months under this chronic exposure regime. The results of spawnings of about 30 females over this time showed that the mortality of larvae occurring immediately after yolk absorption tended to be associated with the level of DDT that had been accumulated in the eggs while they were developing in the female parent. This suggests that larval survival of this species can be adversely affected if the parent stock is under chronic exposure to (relatively high) levels of dietary DDT. Under similar treatment the eggs of the anchovy showed negligible DDT residues and survival of progeny was unaffected. The eggs of anchovies were found to have only one-eighth the lipid content of gulf croaker eggs, and it is possible that this limits the accumulation of DDT to harmless levels in the anchovy egg.

DDT and cold shock

Gulf croakers survived periodic 10°C temperature drops for about five months while receiving DDT-laden food, but beyond this point 10 to 50% died in each of four temperature shocks, while controls continued to be unaffected. Though concentrations in the livers of mortalities varied widely, those concentrations tended to be associated with the length of time the fish withstood the low temperature before dying. This suggests that the amount of DDT in the liver reflects concentrations being released as fat from other tissues is metabolized in reaction to the cold shock. The 10°C temperature shock used in these tests put the fish within 1 to1½°C of their lower lethal limit. The net effect of the DDT residues, therefore, was to raise the lower lethal limit of the fish by about 1°C.

Larvae spend most energy swimming

Mr. Vlymen, a UCSD graduate student, made a study of the amount of energy used by a larval anchovy in swimming by incorporating wave parameters of the swimming anchovy body into a time-dependent sinusoidal body displacement function which is used in the iterated energy integrals of his model. The results for the larva of 1.4 cm length was 144.8 ergs/swimming excursion, or 1.85 X 10^{-2} cal/hr using known swimming excursion rates. This result implied that virtually all of the energy used during early development is expended in swimming by the larva. A manuscript describing this work has been accepted for publication by the *Fishery Bulletin*.

Economics of Aquaculture

Davis
R/FA-3

Warren E. Johnston

Can an economic model for an aquaculture facility based on work with the scarce and expensive American lobster, *Homarus americanus*, provide the key to culturing less complicated edible marine animals?

Flow chart for closed-system culture

Two primary accomplishments of this project under its first year of funding include collaborative development (with R/FA-4) of a detailed flow chart for closed-system culture and of a simulation model of physical production capable of generating physical input and output information for subsequent economic analysis. The flow chart description of a culture facility includes elements for breeding stock storage, egg laying tanks, kreissel rearing of larvae, juvenile and mature growing stages, and the physical systems needed to support the hypothesized culture system. Flows needed to sustain culture in the system include: 1) *inputs*; Food, heat, power, air or oxygen, sea water circulation, and transfer of live individuals and 2) *outputs*: Solid waste removal, liquid waste removal, venting circulated water from the system, removal of dead individuals due to mortality. and removal of live individuals to market. Given the culture system flow-chart and available physical and biological information, first approximations of subsystem and total system costs are now being synthesized. The simulation model includes state or level variables defining the production surface with dimensions for cumulative cost and heat, food, labor, and oxygen requirements of the system, and rate variables which consider growth and mortality rates and changes in heat, food, labor, and oxygen inputs in the physical production system.

Annotated bibliography

The second major accomplishment was the publication of an annotated working bibliography of information sources and previous economic analyses for *Homarus* and other selected crustaceans and mollosks. The bibliography was prepared to support this research effort, but is also potentially useful and available to others with interests in economic evaluations of these species with potential for aquaculture.

Professional Placement

Collinsworth, Don W., Economist, State/Federal Dungeness Crab Project California Department of Fish and Game

Aquaculture of the American Lobster

Davis
R/FA-4

Robert A. Shleser

The development of mariculture is dependent on ability to control and economically optimize all aspects of the biology and environment of the species chosen for culture. The aquaculture group at Bodega Bay is investigating simultaneously a number of problems relevant to the design of a commercial facility for *Homarus americanus*.

All phases of the reproductive process, mating, egg maturation and deposition, and temperature-controlled manipulation of hatch data, have taken place in our laboratory.

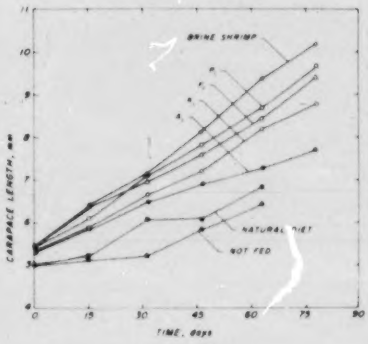
Routine procedures to accommodate these long-term processes have been developed and are being continued.

From November to August, we produced a ready supply of post-larval lobsters to incorporate into many experiments. This has given us an opportunity to refine the rearing phase to the point where 90% survival of a brood is not uncommon. Infestation of the filamentous marine bacteria, *Leucothrix mucor*, can reduce this to 10% or less, but UV sterilization, constant monitoring of bacteria on culture vessel surfaces, and elbow grease have allowed us to control the problem and retain high survival without resorting to antibiotics or other more drastic methods which may affect a future development.

Live brine shrimp as food

The routine rearing of larvae in a semi-closed system has allowed us to zero in on the actual cost of post-larval production using live brine shrimp as a food. An alternative food, *Daphnia*, was also used and was found to be nutritionally adequate as well as offering a potential for lower cost and constant availability. Live adult brine shrimp, as compared to previously used minced clam diets, proved an excellent diet for juvenile lobsters. The brine shrimp have therefore been chosen as the nutritional baseline for the improvement of the artificial food to be used during the next year. To date, extensive trials with several artificial foods; trout chow in succinylated binders, commercial shrimp foods and the like, have not produced a diet that yields commercially acceptable growth. A complete nutritional analysis of the brine shrimp done on the Davis campus has given us guidelines for the composition and relative performance of artificial foods. By constructing a matrix of the components of brine shrimp and of the less successful artificial foods we have already tested, we will be able to make qualitative and quantitative judgements to be incorporated into the next generation of diets. Similar composition analyses have likewise been performed with the lobster itself. In future food trials a number of animals will be sacrificed and analyzed in order to pinpoint the biochemical nature of any dietary deficiency.

In addition to evaluating foods, other considerations for lobster diet and growth have been examined. Juvenile lobsters fed at different frequencies, ranging from one to three days, grew at significantly different rates. Daily or more frequent feedings yield the highest growth rate. These studies are now extended to define precisely the satiety levels.



Physical constraints

Growth is also constrained by the physical dimensions of the container in which the lobster is held. In a series of five habitats, ranging from three (3) to twenty-eight)28) square inches it was found that the animals held in largest containers achieved double the growth, on a wet-weight basis, of those in the smallest habitat. When the configuration of the similar areas was varied, using circular, square and retangular shapes, it was found that limitation of growth was dependent on area with no significant differences resulting from configuration.

The initial accelerated-growth experiments with lobsters determined that growth was approximately trebled at a temperature of 22°C compared to an average ambient temperature of 14°C at Martha's Vineyard. We have further refined the temperature/growth relationship over a range of temperatures expected to be encountered in the many geographic areas in which a commercial enterprise might be established. Preliminary results indicate that growth is optimal at 21°C.

Food and waste

The production of food and fecal waste has been examined at the individual animal level:

We have completed preliminary experiments which define the ammonia production of various-sized animals fed several diets.

Ammonia, the major toxic product of lobster metabolism, is a factor of major importance to the design of intensive water reuse systems. Levels acceptable to the animal, defined by extensive bioassays, are maintained by only two means, increased

new water inputs or biological filtration.

Biological filters with populations of nitrifying bacteria have been operated and their exact ability to convert toxic ammonia to relatively innocuous nitrate is being quantified.

The Chemical Oxygen Demand (COD) production of waste food and fecal material of several size classes of lobsters has been determined. These criteria have already been incorporated into the design of the Bodega Aquaculture Facility funded by the California State Legislature. The COD loading per weight of animal is known and gives us valuable design data for sizing treatment facilities in our new installation and eventually in a commercial facility.

Fabricating tanks

We have found the hand fabrication of large numbers of tanks to be an expensive and time consuming process. We have, therefore, consulted several firms in the plastics fabrication industry with some very satisfactory results. Tanks that previously cost $5/linear foot are fabricated with a vacuum- forming process for less than $1.50. Another process, injection molding, offers the solution to producing large numbers of inexpensive, durable, individual habitats for commercial culture. Although we cannot justify the large initial cost of molds used in this process, we have obtained unit costs which provide real-cost data for the analysis of commercial plant capital costs.

We have devised a tank for juvenile rearing which is periodically flushed by activating an external standpipe to siphon by means of a time-relay controlled solenoid valve. The net effect is that particulate waste is agitated and removed from the tank floor and the time-consuming and wasteful use of man-power for cleaning is reduced. Growth studies of lobsters in this environment indicate that this situation may yield growth rates that exceed those previously documented in earlier systems.

Thermostatic control, filtration are stable

Thermostatic control of our systems is stable and has proven extremely reliable over the course of a year's operation. Filtration components have run continuously and efficiently allowing us to load systems with up to a pound of lobster per cubic foot of volume, while only exchanging the volume of the system on a once-daily basis. Even more effective reuse systems are in use on the Davis campus where experiments conducted by Davis-based members of the group are located. The Davis lab, like Bodega, has reared hundreds of juveniles from the egg. The Davis lab, however, has done much of its culture using artificial seawater. These multi-media filters have been so effective that some culture systems have run for six months without replacement water and the lobsters grow at rates equivalent to their Bodega cousins.

Success depends on economic analysis

The success of a commercial enterprise will depend on an economic analysis of the biological data we have obtained. The systems engineer and economist have generated a model designed to serve the project in two areas. First, it exists as a means of evaluating data derived from many experiments. As data is accumulated, culture variables, such as growth as function of temperature, are integrated into the sensitivity model which will describe the relative cost of each component of the model. Second, once the relative costs are known, the model gives us a sophisticated management tool to assess experimental priorities.

An important feature of the sensitivity model is that although it has been conceived to evaluate lobster culture, it is directly applicable to any aquaculture species.

An American Lobster Fishery in California

San Diego
State University
R/FA-5

**Richard F. Ford and
Charles O. Krekorian**

***Homarus americanus* proves to be too agressive a companion for California crustaceans in nature. But the visitor from the Northeast takes well to controlled aquaculture in warm water effluent from a San Diego Gas & Electric Company power plant.**

Sea Grant investigations have been underway at SDSU since 1970 to evaluate the feasibility, as well as the potential benefits and dangers, of introducing the American or New England lobster (*Homarus americanus*) into California as a fishery resource. The study was prompted by interest from the private sector in attempting to transplant the species, and by concern among governmental agencies and the scientific community about possible adverse ecological effects that might result. Thus it has been conducted as a careful pilot evaluation designed to provide the concerned state and federal agencies with the information necessary to make a rational decision about the transplant. Our approach, which has involved interrelated studies of behavior, ecology, and aquaculture described in this report, may serve as a model for transplant evaluation studies conducted in the future.

During the past year, several members of our research team have provided advice and assistance to the California Department of Fish and Game in developing standard guidelines and procedures for the evaluation of proposals to introduce exotic species into the state. These individuals have been asked to serve as part of an advisory group to this agency, which will assist in evaluating future proposals for species introductions.

Predicting ecological effects

Detailed laboratory studies of food preferences, feeding behavior, patterns of activity, and social interactions of the American lobster (*Homarus americanus*) and similar crustaceans native to California, including the California spiny lobster (*Panulirus interruptus*) and the rock crab (*Cancer antennarius*) have provided particularly valuable results. This information is important both in predicting the ecological effects and introduced population of American lobsters might have in California waters and in better understanding the biological requirements of commercially important crustacean species native to the state.

Electronic monitoring of their feeding activity confirms the fact that all three of these species are active predators which spend considerable time searching the bottom for food. Both the American and the California spiny lobsters are nocturnal feeders, exhibiting a peak in feeding activity during the twilight period following sunset. In contrast, the rock crab appears to be more opportunistic and feeds at a moderately steady pace throughout the day and night.

American lobsters at the ages of 10 weeks, 10 months, and 10 years. The 10-month-old juvenile is approximately four to five times the size of juveniles of similar age cultured in the colder seawater of the Atlantic.

The American and California spiny lobsters also show very great similarity in the foods they prefer. In contrast, the foods preferred by the rock crab are, for the most part, different from those of either lobster species.

Each of the three species has a distinct and stereotyped pattern of feeding behavior. We have found that when a limited amount of food is placed in an aquarium containing California spiny lobsters and rock crabs, each seems able to locate and eat the food about as quickly as the other. However, when an American lobster is combined with either of these native species, it is usually the first to locate and eat the food. This indicates to us that the presence of the American lobster may change and possibly inhibit the normal feeding activities of these California crustaceans.

Lobster confrontations

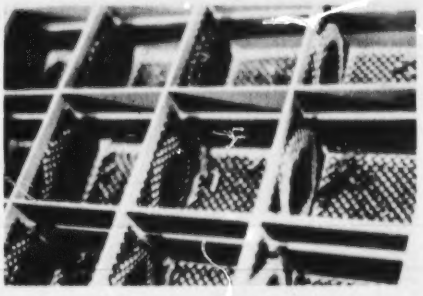
We have recently completed detailed studies of aggression and other social interactions between the three species by placing them together in large pools and repeatedly observing their behavior through viewing windows. Our results allow us to predict fairly specifically what might happen if California spiny lobsters or crabs and transplanted American lobsters were to encounter one another in the ocean. For example, when the two lobster species confront one another in our observation pools, aggression by the American lobster causes the spiny lobster to leave the area approximately 73% of the time. Similarly, when only one shelter or "home" is available in a pool, the American lobster is able to take over and successfully defend the shelter from intrusions by its spiny lobster "adversary" about 75% of the time.

This and other related information obtained from our studies of feeding and social behavior indicates that, if successfully transplanted, the American lobster could have serious adverse effects on our native spiny lobster population. Associated, potentially dangerous disease problems have also been identified by Mathewson and Schapiro. Thus, we believe that the American lobster's introduction into the ocean off California is inadvisable.

Aquaculture models

As research and publications concerning the potential ecological problems involved in transplanting *Homarus americanus* are completed, work at our Scripps laboratories has been directed more and more toward solving problems concerned with the commercial aquaculture of the American lobster, from the egg stage to a marketable size of about one pound. Lobsters hatched and held in our culture systems in seawater of normal temperatures in San Diego for approximately 16 months have now reached a size of almost ¼ pound, which represents a growth rate four to five times that typically shown by lobsters in the Atlantic off Massachusetts. Several novel culture systems have been developed, such as multiple channel plastic raceways which incorporate rapid waste removal and electric heating systems. These culture systems have been stocked with young lobsters for growth and survival studies now in progress. A study to determine the effects of confinement in small individual culture containers is being repeated. The new results continue to suggest that it may be possible ot use a rearing container not much larger in bottom area than the adult body length squared.

Several new mass-rearing studies, not yet completed, have shown interesting preliminary results. For example, it appears that increasing the amount of food given lobsters in mass-rearing systems above the level necessary for normal growth will do very little to reduce mortality caused by cannibalism. Results of a related study indicate that the availability of one or two tube-like shelters for each lobster in the tank can significantly reduce cannibalism, but that providing more shelters will not cause a further decrease in cannibalism. Similarly, providing successively larger tank areas for roaming and foraging, and also presumably for escaping from other cannibalistic lobsters, will not reduce cannibalism.



Raceway culture system.

Standardizing larval culture

During the past two years we have also helped to develop and evaluate standard methods of culturing American lobster larvae. The results of a related study recently completed in our laboratory provide valuable information about the specific daily food ration requirements of these larvae. Several hundred larvae were reared individually in miniature floating "cages" at both normal and elevated temperatures. They were fed standard food rations ranging from one to 16 live adult brine shrimp per day and their growth and survival observed. Larvae reared on four to six shrimp per day showed the most rapid growth, attained the largest size, and had the highest rate of survival.

Choosing suitable food

There still is no suitable artificial food for lobster culture. Adult brine shrimp appear to be nutritionally adequate, but at $1.00 per

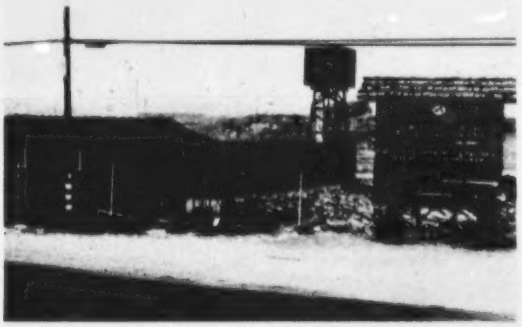
pound this food obviously is not an economical choice. We have developed and are testing the use of several different additives for fish meal trout chow, which we earlier found inadequate as a sole diet. Additives such as brine shrimp, crab, crayfish, and shrimp processing wastes are being evaluated in the hope that if some nutritional element, such as carotenoid pigments, or thiamine is the missing item in the trout chow diet, it might be added during manufacture at a cost low enough to permit economically viable lobster culture. In cooperation with a commercial fish food producer, we also are evaluating a new high-protein alginate-imbedded mix of various wastes from shellfish processing plants. Its cost is now approximately $.50/lb., but this could be reduced if high volume sales are possible. Experiments also are in progress on the fluidization of food particles in our raceway culture system.

Unique laboratory

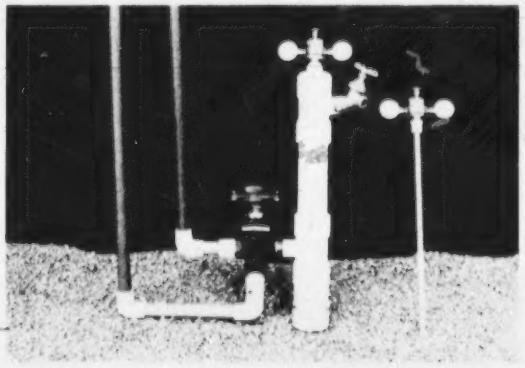
A major portion of our time during the year was spent in completing a new and unique thermal studies laboratory in Carlsbad, California, made possible by strong interest and financial support from the San Diego Gas and Electric Company. Located adjacent to the thermal effluent pond of that company's Encina Power Plant, the laboratory has access to almost unlimited quantities of warmed seawater. Related systems development work has involved highly successful trial runs with our water temperature control system. This employs pneumatic three-way seawater mixing valves and pressure-proportioning thermostats to blend seawater of normal and high temperatures to a preset level and hold that value within 1°C regardless of changes in supply water temperatures, pump output pressure, turbidity or fouling. Every tank and tray in the laboratory is supplied with inputs for seawater of normal, warmed, or intermediate (mixed) temperatures. We are now in the process of moving lobsters from our Scripps Institution laboratories and will soon begin large scale experimentation on their culture at elevated temperatures.

Holding females until molting

We have several new trials underway in which recently berried female American lobsters have been held until molting, then mated with male lobsters and held under conditions that will reduce the time needed for egg production. Other work with females already in berry is aimed at reducing the time required for egg development to hatching. We believe that our work on brood stock management involves one of the most important and least understood areas of lobster aquaculture.



In the process of our work, we continue to provide formal and informal advisory services to many individuals and companies interested in aquaculture or maintenance of live lobsters shipped to California for sale.



Three-way seawater mixing valve and pressure proportioning thermostats developed for highly flexible and accurate temperature control at the Encina thermal studies laboratory.

Protective Measures For Lobster Aquaculture

San Diego
State University
R/FA-7

**James H. Mathewson and
Harriette Schapiro**

As part of the evaluation of the feasibility of introducing American lobsters into California fisheries, a study was conducted of the effect on native spiny lobsters of *P. Homari*, a lethan bacterial disease affecting five to fifteen percent of the wild population of *Homarus americanus*.

Approximately 10^5 bacteria/kg body weight of *P. homari* are lethal for 50% (LD^{50}) of the California spiny lobsters injected. This is in contrast to the American lobster which can be killed by very low numbers of the bacterium. The normal route of transmission is through breaks in the exoskeleton and the entrance of *P. homari* through these ruptures of the integument. The average American lobster dies of gaffkemia at approximately 10^8-10^9 bacteria/ml hemolymph; California spiny lobsters die at approximately 10^7-10^8 bacteria/ml hemolymph. Thus, despite the higher lethal dose of bacteria needed in the California spiny lobster, it is still possible for an injured spiny lobster to be infected by a dead or dying gaffkemic American lobster. Therefore, transplantation of American lobsters could have adverse effects on the population of California spiny lobsters.

Malachite green as lobster dip

Repeated sampling of newly imported American lobsters showed that nearly all of the animals had *P. homari* on their exoskeletons. This possible transmission of the bacterium could be the cause of outbreaks of gaffkemia. Following a suggestion of Dr. Robert Shleser, we have investigated the use of malachite green as a lobster dip. Data seems to indicate that low levels of this dye in aquarium water may be lethal for *P. homari*.

Current work is underway to determine the exact concentration and length of exposure necessary to clear *P. homari* from the lobster's exoskeleton. Hopefully, this dose will not affect the lobster.

Immune responses, which are highly developed in the vertebrates, are not as well defined in the invertebrates. Decapod crustaceans do seem to have well developed cellular responses. These cellular responses seem to result in the enhancement of phagocytosis of the immunizing substances. We used the attenuated form of *P. homari* to immunize California spiny lobsters against 200 times the LD^{50}. This is the first use of a live attenuated bacterium to immunize a decapod crustacean and the first protection of a susceptible species against infection by *P. homari*.

The extent and duration of immunization and the exact nature of the protection are being investigated. The feasibility of immunizing American lobsters is being studied.

Abalone Culture

San Diego,
San Diego
State University
R/FA-8

David L. Leighton

Of the plant-consuming creatures of the shallow rocky sea floor, the abalone is the most desirable and these mollusks seem amenable to culturing, perhaps by reseeding depleted beds with hatchery-grown "seed" animals. San Diego researchers spent this second year of study appraising nutritional requirements and influence of temperature and heredity on survival and growth of juvenile abalones.

Algae (*Platymonas, Isochrysis, Amphora, Nitzxchia*) were compared as foods for post-larvae. *N. subcapitellata* (tentative ident., Dr. R. Lewin) isolated from local diatom flora outranked others. Diets (fish and turtle rations) compounded in Calcium alginate gel produced encouraging results when fed to juveniles.

Progeny from several spawnings were observed for more than a year to compare specific growth rate under laboratory conditions (see table, 1972 annua report). Green abalone produced in September, 1972, grew more slowly than those the previous year. At 11 months, a sample of 68 averaged only 18.8 mm compared to 30.0 mm for a small group last year. This year's colder ambient seawater could have influenced their growth, but size distribution in the Point Loma population indicates 30-35 mm for first year

growth this year in nature. Possibly the laboratory population is stock with low growth potential.

Very young do not survive

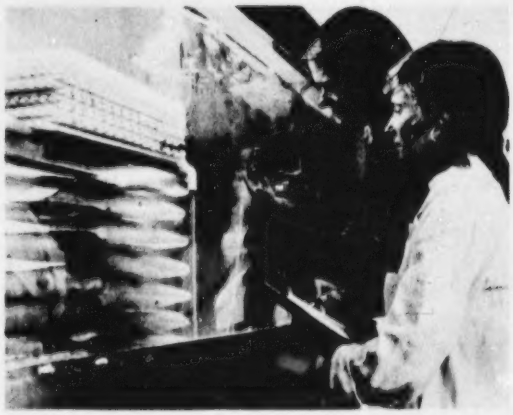
Attempts were made throughout the last year to introduce larvae and juveniles of pink and green abalone to the CMA culture system at Cayucos. Very young abalone did not survive; however juveniles have shown moderate growth when placed in concrete raceway tanks used chiefly for rearing red abalone to market size (75-125 mm).

Minor emphasis was given pathogens and micropredators. Since there were always some survivors in declining batches of larvae and post-larvae, disease does not appear likely (though not ruled out) to have contributed to mortality. Ciliate infestations did occur, but attacks appear restricted to moribund or weak individuals. Physiologically stressed post-larvae were attacked by amphipods (e.g., *Elasmopus* sp.), juvenile crabs and starfish which were intentionally allowed to enter experimental cultures with unfiltered water. These predatory forms and competing grazers (e.g., certain copepods) are very difficult to exclude once scale of the system is increased.

Hybridization experiments planned were slighted since coincident spawning of parental types occurred only once. In that instance red x pink larvae were obtained, but fertilization was only about 5%. Juveliles from this cross did not survive beyond three months, but the cross (possibly its reciprocal) is represented by specimens from nature.

Contribution to related programs

A not insignificant offshoot of the study has been the contribution of larval and juvenile abalone to many other investigators in related programs, some of whom are receiving support from the Office of Sea Grant. Two publications (Leighton 1972 and Leighton, 1974-in press) and numerous public presentations (in addition to advisory services) have resulted from the study.



Controlled rearing of abalone.

Cooperating Organizations
La Jolla Laboratory, Southwest Fisheries Center
California Marine Associates, Shellfish Laboratory, Cayucos, California

Biological Stimulus For Spawning in Abalone

Wilfred J. Wilson

The red abalone (*Haliotis rufescens*) seems to get fatter and more ready to spawn when its surroundings are dark and cold. The reproductive cycle of the mollusc might also be predictable through analysis of the cyclic changes in the appearance of certain brain cells.

Potential triggers for spawning

Several environmental factors can be considered as potential triggers for spawning in red abalone. Two of these external factors, temperature and photoperiod were studied to determine if they could be correlated to GBI. Change in photoperiod did not appear to affect the reproductive pattern of the population studied. However, a definite correlation was found to occur between temperature and GBI (gonadal bulk index, an indicator of reproductive maturity): decreasing temperatures coincided with decreasing GBI. This suggests that spawning may be caused by declining temperatures, which are coincident with upwelling. Rich nutrients would be advantageous to the survival of developing veligers.

Although environmental factors often stimulate the commencement of gametogenesis, hormonal systems are involved in the control and regulation of this process. In many molluscs the reproductive cycle is characterized by cyclic changes in the appearance of certain cells near the cerebral ganglion. Sixty serial microsections of the cerebral ganglion were made from the animals used in the photoperiod study above. One matched pair from each animal was stained by paraldehyde fuchsin and the other with Masson's Trichrome for analysis. The presence of juxtaganglionic cells (fine granular cells diffusely distributed in the connective tissue exposed to the base of the cerebro-neural connective tissue) in sexually maturing adults (adults not yet ready to spawn) is being studied.

Seaweed Resource Management

Michael Neushul

Santa Barbara
R/FA-10

Algologists are taking a variety of paths toward development of techniques and information needed for management, cultivation and harvesting of seaweeds, one of California's richest and least tapped resources—a "plant by plant" examination of the algae; laboratory and field studies, some depending heavily on successful methods from Japan and China; setting up a network of advice and assistance to and from seaweed industries within the state and in the Orient; and working with advisory services to inform the public about the value and importance of the underestimated resource.

Natural populations of the agarweed *Gelidium robustum* have been studied, and a bioeconomic harvesting model completed. This model, which defines how best to utilize this resource, is based on biological and economic information. The report has been distributed to the California Department of Fish and Game, and to all seaweed harvesting companies in the state. The importance of such information for sound resource management practices has led us to begin to develop a similar model for the giant kelp, *Macrocystis*. We have been studying natural recruitment in a kelp bed for over one year and have used and evaluated aerial photographic techniques for examining the condition of *Macrocystis* beds. We have defined the parameters for our Macrocystis model, and from our aerial surveys and with the cooperation of the kelp companies have defined the sites for biological data collection. We have begun to study the productivity of *Macrocystis* and have developed a large hydrodynamic chamber for the laboratory—a "water tunnel"—and field equipment for determining the photosynthetic capacity of whole blades of *Macrocystis* in the laboratory and in the sea.

Japanese-style culture

Encouraged by the growth of *Laminaria farlowii* on our Japanese style culture lines, we continued study of the enconomics of this resource. Measurement of physical characteristics of our rope line cultured plants and local natural populations was performed to obtain a better idea of the eventual commercial potential of this plant. Unfortunately, based on this work and information from our Japanese sources, this species will not be among the more valuable of California's marine crop plants, unless there is a large change in world economics.

Porphyra work encouraging

Our work with the valuable plant *Porphyra* has been encouraging. We have evaluated the three most accessible California *Porphyra* species and have selected one which shows the most potential-*P. nereocystis*. Natural populations of this plant have been surveyed, and both of the life history stages have been obtained and are being studied in the laboratory. Attempts to transplant this species to our outplanting areas have not been successful.

We have successfully produced what we believe are the first samples of the commercial product nori from California *Porphyra* sp. using Japanese drying frames and racks. These racks and frames will also be used for our trial harvest of *P. nereocystis* natural populations later this year. After long delays, we have finally also obtained "hibi" culture nets and a floating net support system for use in cultivation of *Porphyra*. In the field, our environmental monitoring system has been used to obtain our first real-time continuous submarine illumination measurements at our sea site. These measurements, made by cable connection to the buoy-sensor system, represent the last

step prior to direct radio transmission of ocean bottom light data to the laboratory. The radio transmitter-receiver systems have been completed and tested and are undergoing final preparation for ocean placement.

Varied advisory activities

Our advisory activities have been varied during the past year. The first jointly held statewide plant and animal maricultural conference took place with our assistance on this campus. This conference may represent the starting point for a long-term cooperative University of California aquaculture program.

We have responded to State Coastal Commission requests for information, consulted with kelp harvesters about kelp disease problems, and given public presentations on our work.

Foreign scientists visit and work

Interest in our work is evidently growing as indicated by continuing visits to our laboratory by scientists representing foreign governments. Dr. J. Tripodi (University of Naples) has recently returned to Italy after spending six months with us, working on studies of red algal spores. His completed paper on this work has been submitted to the Journal of General Microbiology. Other foreign visitors who have sought our advice include: a) Dr. R. Perez (Institut Scientifique et Technique des Pêches Maritimes, France) and other members of the group traveling with him—concerning the culture of *Macrocystis* in the Atlantic. b) Mr. S. Torii (Hakodate Fisheries Experimental Station, Hokkaido, Japan), concerning propagation of marine algae, underwater microscopy, and culture of *Laminaria* in Japan. c) Dr. T. Hori (Tokyo Kyoiku University), concerning electron microscopy of brown algal cells.

Further evidence of interest in our work is shown by requests we have received to present invited papers at: 1) a special Cal. Tech.-SIO symposium on Ocean Pollution (Nov. 11-15; 2) the December, 1973, meeting of the Western Society of Naturalists—in a symposium on the biology of macroalgae; and 3) the forthcoming International Seaweed Symposium in Bangor, Wales, U. K.

Theses Completed

Silverthorne, George Wesley. Optimal Production from a Seaweed Resource

Professional Placement

Silverthorne, G.W., to Washington Department of Fisheries Laboratory, Aberdeen, Washington

Gelidium Resource Management

Donald C. Barilotti

San Diego State University R/FA-12

International events during the past two years have nearly tripled the market price for raw agar solids. In addition, they have caused a near-total failure of traditional sources that provide export agarweed to the United States. As a result of these market conditions, agar producing companies in the U.S. are now faced with either decreasing production, or establishing domestic sources of agarweed.

In conjunction with the American Agar and Chemical Company (San Diego), we have been determining quantitative biological parameters relevant to the management of agarweed resources in southern California. In addition to those directly associated with resource management, studies are being conducted at a sublittiral site off Point Loma and in the laboratory to determine ecological factors that effect the growth of agarweeds, primarily *Gelidium robustum*. The results of these experiments are used to interpret field results at agarweed harvest sites, and provide information needed for possible resource enhancement and mariculture ventures.

Biomass increases with depth

The biomass of organisms (epiphytes) growing on *Gelidium* increases exponentially with depth at the harvest study site. This relationship is of particular interest to the harvester in that transportation costs before processing are related to the weight of the uncleaned agarweed. The increased epiphyte load with depth may be a key factor responsible for the decreased abundance of *Gelidium* with depth. The increased epiphyte biomass makes the fronds more susceptible to being broken loose from the substrate in

storms due to the increased hydrodynamic drag. It also increases the probability of motile grazers such as fish pulling loose fronds as they feed on the encrusting epiphytes. Experiments are being planned to test the validity of these hypotheses.

Long term studies of regrowth after harvesting and seasonal agar fluctuations are in progress. Results of these studies will be available for the next progress report.

Mariculture prospects

The mariculture prospects for the agarweed *Gracilaria verrucosa* are being investigated. *Gracilaria's* rapid growth in calm water habitats such as bays and estuaries (nearly 1 cm growth per week has been measured in pilot raft studies conducted at Mission Bay) makes it a likely candidate for mariculture. To date, all specimens of *G. verrucosa* from the San Diego area have yielded a gel strength that makes them unsuitable for use in the production of high grade pharmaceutical agar. Further mariculture studies of this agarweed are contingent on ways of increasing the gel strength of the agar, and on market information such as price and demand for low grade sources of agar.

Salt-Tolerant Plants

Davis
R/FA-13

Emanuel Epstein

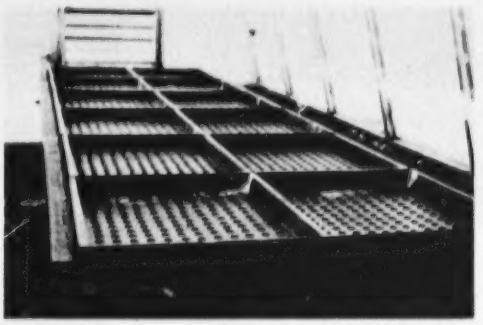
Coastal and other land areas with a high salt content as well as salty water could be made more productive through the development of salt-tolerant plants. Although most crop plants are sensitive to salt, many to an extreme degree, many kinds of wild plants are salt-tolerant, even to sea water or equally saline environments on land. Many species of plants—for instance, barley, an important crop plant—include varieties, races or strains that vary in salt tolerance and so open the way to genetic manipulation of this trait.

We chose barley because we had performed much previous work on salt transport in this species. Also, there are available on the Davis campus seeds of composite crosses of thousands of barley varieties and races from many parts of the world, including regions with extensive saline areas.

Screening plants

We proceeded to screen plants from seeds derived from such a composite cross for salt tolerance as follows: We installed large tanks for solution culture, occupying an entire greenhouse (Figure 1). Perforated covers are supported above the solutions. Cheesecloth is placed on top of these covers and a seed is placed on it above each perforation. A standard nutrient solution is used to supply all essential mineral nutrients, and this solution is then progressively salinized. As the seedlings grow to a size of 5-6 cm inert granules ("Sponge Rock") are poured on the covers to provide mechanical support for the plants (Figure 2). In this manner 9640 plants can be screened in one run.

The first screening run lasted 120 days, the last 45 at the maximal salinity used, namely 400 millimole sodium chloride per liter, approaching the concentration of this salt in sea water (457 millimole per liter).



One of the 700-liter tanks in the greenhouse in which barley plants grew in progressively salinized solutions. Perforated covers for supporting the plants are shown.

Few plants killed

Contrary to expectation, this severe salinization killed only a few plants outright, although it impaired the growth of all the plants to varying degrees. But barley is a grain crop, and in terms of the production of grain (seed set), this selection experiment was highly successful. Of the plants tested, 94.2% failed to set any seed. The 5.8% that

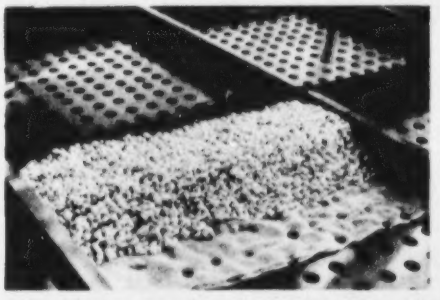
did form seed therefore represent a rigorous selection of salt tolerant individuals. They will be used in further screening runs, in a breeding program, and in experiments designed to discover the physiological and metabolic adaptations that render these plants tolerant to salinity.

Evidence for genetic control

The rationale for a breeding program comes from an independent experiment in which third-generation progeny from a cross of a salt tolerant and a salt sensitive strain of barley was used in experiments on the absorption of chloride, which according to our preliminary findings serves as a rapid test for salt tolerance. Statistical analysis provided strong evidence for genetic control of chloride absorption, and by inference, of salt tolerance.

Galapagos tomatoes

Although the bulk of the work has been with barley we have done some work with other plants. We obtained seeds of a species of tomato from the Galagapos Islands. The seeds came from plant populations growing in different habitats, some, saline, some not. Plants grown from these seeds under identical conditions differed in obvious, visible features, evidence that they represent different races or "ecotypes." Since we started with relatively few seeds from each race we first had to increase the seed supply by growing plants to maturity and harvesting the seed. Germination and growing of the plants presented some time-consuming technical difficulties, so that tests for salt tolerance of the different strains are only now getting under way.



The plant support system consisting of perforated cover, cheesecloth, and Sponge Rock granules.

Fishes of the Santa Barbara Kelp Forest

Santa Barbara
R/FA-14

Alfred W. Ebeling

If the fishes of the Santa Barbara kelp forest can be charted and codified and their population density and interrelationships predicted, scientists will be able to plan and regulate the fishery as well as increase sports fishery of those species not currently sought.

Our objectives were: (1) community assessment—first determining kelp-bed habitat groups (fish "communities") and their interactions, then comparing these groups between mainland and island areas from year to year; (2) measurement of ecological niche breadths—an analysis of resource needs of the 21 most important resident species shown by the initial resolution of groups by factor analysis; and (3) observation of the diel changeover—a comparison of distributional and behavioral patterns between day and night. Estimates of community parameters appear sensitive enough to show the early signs of possible pollution damage. The breadth of a species' ecological niche may indicate its survival potential in a changing environment and its "catchability" in an underexploited "pan fishery." Diel studies have verified and rationalized the "best times" for fishing. More than 600 underwater man-hours of scuba diving and incalculable hours of SCUBA preparation, laboratory work, and data analysis were expended in our effort.

TABLE 1. Abundance and diversity of fishes in Santa Barbara mainland and Santa Cruz Island kelp-bed communities, compared between bottom and canopy habitat groups and among yearly sample sets.

Habitat Group	Locality	Year (Sample Set)	No. of Samples (Cinetransects) in Sample Set	Total Individuals in Sample Set (pooled)	Density, Log No. Individuals/Sample, Mean ± Standard Error	Coefficient of Variation of Density, ± S.E.	S, Total Species Counted in Sample Set (Pooled)	SD**, Scaled Standard Deviation Index of Diversity of Sample Set (Pooled)	NM**, Fager Scaled "Number-of-Moves" Index of Diversity of Sample Set (Pooled)	H', Shannon Index of Diversity of Sample Set (Pooled)	H'', Pielon Index of Diversity of Sample Set Based on Randomly Ordered, Sequentially Pooled Samples, Mean ± S.E.	H, Brillouin Index of Sample Diversity, Mean ± S.E.	b, Coefficient of Linear Regression of Sample S (Species) on Log Sample N (Abundance), ± S.E.
Bottom	Mainland	orig	48	1500	1.34 ± .06	86.9 ± 14.0	24	.66	.28	2.31	2.36 ± .09	1.09 ± .06	4.78 ± .64
		71	25	587	1.30 ± .05	60.0 ± 11.1	20	.70	.33	2.31	2.39 ± .08	1.32 ± .05	5.43 ± 1.29
		72	45	2140	1.63 ± .03	51.9 ± 10.3	23	.72	.33	2.42	2.51 ± .06	1.59 ± .03	5.04 ± 1.28
		73			(Statistics of the 1973 sample set are not yet completed)								
	Island	orig	46	3180	1.73 ± .05	73.8 ± 11.1	23	.67	.29	2.27	2.41 ± .06	1.36 ± .05	5.24 ± .90
		71	37	1240	1.46 ± .04	64.4 ± 10.1	20	.72	.36	2.35	2.45 ± .05	1.46 ± .04	4.49 ± 1.08
		72	45	1516	1.46 ± .04	56.0 ± 10.8	23	.77	.41	2.61	2.60 ± .04	1.54 ± .04	8.65 ± 1.04
		73											
Canopy	Mainland	orig	27	1854	1.66 ± .09	74.4 ± 14.7	14	.48	.24	1.64	-	0.83 ± .08	2.56 ± .91
		71	13	522	1.38 ± .16	84.7 ± 25.9	11	.39	.18	1.30	-	0.51 ± .09	1.09 ± .44
		72	31	3031	1.85 ± .09	65.2 ± 17.9	12	.30	.10	0.98	1.04 ± .19*	0.68 ± .06	1.97 ± .48
		73											
	Island	orig	27	3290	1.81 ± .10	124.0 ± 34.1	16	.40	.16	1.42	-	0.82 ± .08	1.89 ± .88
		71	22	2442	1.77 ± .14	90.8 ± 22.3	13	.37	.11	1.03	1.05 ± .13*	0.68 ± .05	2.04 ± .29
		72	38	3847	1.85 ± .07	69.4 ± 25.4	13	.53	.23	1.57	1.59 ± .08*	1.00 ± .05	3.33 ± .58
		73											

* Median ± S.E., because of distributional skew.

** Measures the "evenness" (of distribution of individuals among species) component of diversity; the larger the value, the more evenly distributed, i.e., the less dominance by one or two species.

TABLE 2. Correlation of Species Composition among Sample Sets from Mainland and Island Bottom Communities

Numbers in the matrix are the Kendall coefficient of rank correlation, tau, which may be used as an index of similarity between communities (Ghent 1963, 1972). The San Diego mainland values were calculated from "sight-transect" data in Quast (1968).

	Mainland Orig. (1969-70)	1971	1972	Island Orig. (1969-70)	1971	1972	San Diego Mainland
Mainland Orig. (1969-70)	--						
1971	0.49*	--					
1972	0.39**	0.40**	--				
Island Orig. (1969-70)	0.03	0.07	0.14	--			
1971	0.00	0.00	0.11	0.55*			
1972	0.12	0.00	0.03	0.57*	0.57*	--	
San Diego Mainland	0.19	0.03	0.29	0.49*	0.55*	0.33	--

* Significant at the $P < .05$ level

** $.05 < P < .01$ (the others are non-significant)

Degrees Awarded

Alevizon, William S., Ph.D., 1973

Baines, George W., Ph.D., 1973

Meek, Robert P., Ph.D., 1973

MARINE PRODUCTS

Davis
R/MP-1

Food Uses of Marine Lipids

Harold S. Olcott

Because edible seafoods contain highly unsaturated fatty acids, exposing them to oxygen in the air can cause rancid odor, off-flavor or discoloration. Experiments with compounds (amino acids such as proline occurring naturally in foods) to halt oxidation while ensuring consumer safety led to the synthesis of proline nitroxide which proved to have limited effectiveness. Antioxidants with broader application are now being sought.

The requirements for suitable antioxidants include effectiveness and safety. Those at present allowed in human foods include the tocopherols, which occur naturally, and a few synthetic phenolic substances of which BHA (butylated Hydroxyanisole) and BHT (butylated hydroxytoluene) are examples. Research work in this laboratory has shown that a class of synthetic organic chemicals known as stable free radicals are extremely effective antioxidants when tested with squalene. Squalene is an unsaturated hydrocarbon that occurs naturally in all animal tissues but in particularly large quantities in some whale oils, and that is particularly suitable for such tests. The toxicology of stable free radicals could be obtained from naturally occurring compounds already present in foods. They might possess both the stablization effect and safety required. The amino acid, proline, had previously been shown to have antioxidant activity.

Nitroxide successfully described

Proline nitroxide was synthesized and isolated and its physical, chemical and antioxidant properties were described. Although it had promising effectiveness in preventing oxidation in anhydrous (waterless) purified lipid systems, in aqueous emulsions of our unsaturated fatty acids, oxidation appeared to be somewhat accelerated when catalyzed by hemoglobin. Most food uses would resemble the emulsion rather than the anhydrous substate. We are therefore continuing to search for antioxidants with potentially greater utility.

The successful description, for the first time, of an amino acid nitroxide has encouraged us to study other amino acids with secondary amino nitrogens. Electron paramagnetic resonance (EPR) spectroscopy is the physical-chemical-analytical procedure used to establish the presence of free radicals. By this procedure evidence has been obtained that the nitroxides of histidine and tryptophane are present in proper reaction mixtures and their isolation is now being attempted.

The utility of new and previously used food antioxidants is being studied with W. D. Brown for modifying unwanted color reactions in frozen skipjack tuna.

Professional Placement

Theresa C. Tom, now employed in the research laboratories of Gallo Wineries, Modesto, California.

Charles Truftgruben, now enrolled in the School of Veterinary Medicine, Univ. of Philippines, Diliman, Quezon City, Philippines.

Studies of Fish Muscle Proteins

Davis
R/MP-2

William D. Brown

Studies of fish muscle proteins to discover the causes of undesirable discolorations in canned albacore and skipjack tuna seem to show that non- enzymatic browning, involving the reaction of a sugar and an amine, might be an important factor. Additives are being evaluated which would enhance the stability of the final pigment of the canned fish and, at the same time, reduce the chances that the color will fade or change when the can is opened.

Our working hypothesis is that ATP, (adenosine triphosphate) present in large amounts in tuna muscle and probably higher in skipjack than other species, is degraded post-mortem through a series of intermediates, including IMP(iodine monophosphate)

and hypoxanthine to ultimately release free ribose. the latter is then free to react with free amino groups in protein, or with free histidine and various derivatives known to be present in tuna muscle, to give brown pigments. Recent data show the accompanying presence of lipid oxidation products (e.g., TBA values of 30 in dark fish versus 3 in normal ones).

Stabilizing desirable canned tuna color

We are evaluating additives that might stabilize the desirable color of canned tuna or that might replace nitrite in canned pet food products. The latter effort is in response to the probability that nitrite might be banned by the FDA from use in such products. As previously reported, esters of nicotinic acid and derivatives of nicotinamide will form a desirable pink color. Unfortunately the color formed is subject to air oxidation, and there is fading upon exposure of the canned material to air. Derivatives of nicotinic acid and nicotinamide are known to have vasodilatory properties. Our continuing work is aimed primarily at chemical modification of these substances to achieve two purposes: enhance the stability of the final pigment and reduce the vasodilatory response.

Oxidation deleterious

It is known from our earlier work and that of others that oxidation of myoglobins (the pigments responsible for color in tuna as well as in other fish and meat products) is deleterious to color in the final canned product. This oxidation may take place during frozen storage, hence we have been interested in studies of low as well as ambient temperatures. Of interest also are means of reversing the oxidation reaction, *i.e.* reduction by chemical, enzymatic, or non-enzymatic means. Recent studies have dealt with the influence of various factors on the stability and autoxidation of photooxidized myoglobins. We recognize, of course, that photooxidation of tuna myoglobin is likely not of direct importance. It is, however, extremely important to fully understand the oxidation mechanism in order better to address the question of its prevention.

Trainee evaluates surface discoloration on skipjack tuna loins subjected to a variety of treatments.

Cooperating Organizations
Star-Kist Foods
Del Monte
Bumblebee Seafoods
NMFS Biology Laboratory, Honolulu
Seafoods Laboratory, Oregon State University

Natural Fermentation Of Marine Products

Davis
R/MP-3

Eli V. Crisan and Martin W. Miller

Allowing marine products to ferment naturally may increase the larder for a hungry world and lead to ways of recovering fishery wastes as useful byproducts or rendering them less harmful to the environment.

Malaysian shrimp paste

Belachan is a fermented shrimp paste used extensively in Malaysia and in other parts of Southeast Asia under names such as kapi, ngapi, trassi, bagoong, or prahoc. It is prepared from a variety of shrimp, particularly Ascetes and Mysid types. A microbiological analysis of 18 samples of belachan obtained from different areas shows that a limited number of bacteria are common to all samples regardless of origin. During the initial stages of fermentation a salt- tolerant species of *Pediococcus* is functional in inducing desirable changes in texture and flavor of the raw materials. As the

fermentation reaches completion, the microflora is composed almost exclusively of six species of the sporeforming bacterium *Bacillus*. Since the spoilage of belechan during and after fermentation is prevented by the addition of 13 to 18% salt, the isolated species exhibit a high degree of salt tolerance. Although the autodigestive enzymes present in the entrails of shrimp and fish have been shown to be responsible for some changes that occur during fermentation of fish/shrimp pastes, the enzymatic activities of the halophilic microorganisms isolated in this study appear to be the major factor in producing an acceptable shrimp paste such as belachan.

Fermenting commercial fish meal

Selected microorganisms exhibiting high lipolytic and low proteolytic activity were isolated from fermented marine products. These microorganisms and a highly lipolytic yeast, *Candida lipolytica* were used to ferment commercial fish meal to determine fermentative changes in lipid, protein, and formethylamine content. Among the organisms tested, filamentous fungi were able to remove 84% of the fat as compared to 74% by yeasts and 60 to 75% by bacterial isolates. Trimethylamine (TMA), a substance contributing to the "fishiness" of the meal, was reduced by 48 and 20% by yeasts and filamentous fungi, respectively, while bacteria increased the TMA content by 64%. The crude protein content (based on Kjeldahl nitrogen) was increased by 5% using *C. lipolytica* as a fermenting agent but analyses of specific components indicated a 54% loss of amino acids. This loss can be minimized or prevented however by providing the fermenting microorganism with a supplementary source of nitrogen for its metabolic needs. The fermented product exhibits improved texture and color qualities, and lacks any trace of "fishy" odor or taste. By controlling the loss of amino acids noted above, fermented fish meal has the properties necessary for becoming a high protein supplement acceptable for human consumption.

Professional Placement

Merican, Z. B.B. Technical Staff, Div. of Food Technology, Food Technology Research and Development Centre, Ministry of Agriculture and Land, Sungei Besi, Selangor, Malaysia.

Yee, S. D. Asian Health Services, San Francisco, CA.

Koyanagi, O. Health Food Project, Nisshin Seifun (Nisshin Flour Co.), Ohi, Saitama, Japan.

Pharmaceuticals from Marine Organisms

San Diego
R/MP-4

D. John Faulkner

An insect growth hormone administered to barnacles under laboratory conditions prevents the fouling animals from adhering to a settling surface but proves less effective in nature. Antibiotic activity is detected in a La Paz sponge.

For some years, we have suspected that insect hormones might cause morphological changes in crustaceans. The pesticide industry, faced with a ban on DDT and other highly chlorinated insecticides, has concentrated its efforts on developing insect growth regulators, whose structures were based on the insect juvenile hormones from *Cecropia*. When Dr. E. D. Gomez, as part of his thesis research, showed that he could successfully rear the acorn barnacle *Balanus galeatus* from egg to adult in the laboratory, we asked his cooperation in testing insect growth regulators on larval stages of *B. galeatus*. We were somewhat surprised to discover that ZR-512 (made available by Zoecon Corporation) caused metamorphosis from the cyprid to the adult stage before settling had occurred. In normal development, the cyprid searchers for a suitable substrate, settles, and only then metamorphoses into an adult. After precocious metamorphosis, the unattached adult is unable to feed by its normal filtering process and ultimately dies.

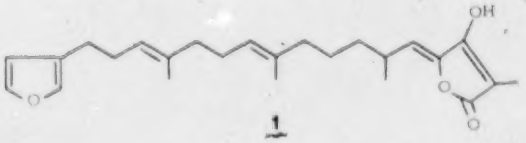
ZR-512 too specific when used alone

Our observations led to speculation that ZR-512 would act as an antifouling agent. Zoecon prepared some test plates containing ZR-512 but without any other antifouling agent. When tested in San Diego Harbour, the plates rapidly became covered with tube worms and other organisms on which barnacles could then settle. We conclude that ZR-512, while effective under laboratory conditions against barnacles, is too specific to be used alone as an antifouling agent. The hormonal approach to control of fouling

organisms remains the most desirable from an ecological viewpoint but, to be practical, must involve several growth regulators.

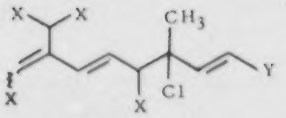
Isolating antibiotic components

On a collection cruise in the vicinity of La Paz, B.C., we collected a small sample of the sponge *Ircinia variabilis*. The sponge showed useful antibiotic activity against *S. aureus*. The antibiotic variabilin was isolated and shown to have a sesterterpene structure 1. Compounds of this structural type are extremely rare and have only been found in sponges. Variabilin is the only sesterterpene reported to have antibiotic activity.



1

We have isolated a number of antibiotic components from the red alga *Plocanium coccineum* var. *pacificum*. All are polyhalogenated monoterpenes. We have not completely separated all components of the complex mixture and have therefore not confirmed the structures. (See formula 2 which covers at least five of the individual components.)



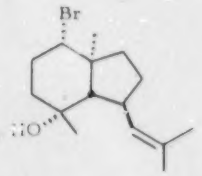
X = Cl or Br
Y = Br or H

2

Assaying proves difficult

Without pure compounds, we cannot assay for antibiotic activity. These compounds are of great interest, since marine bacteria which will grow on media containing them may well attack other polyhalogenated compounds such as so- called "persistent insecticides." Research in this area is in progress in the laboratory of Dr. Fenical at SIO.

We have isolated an antibiotic from *Laurencia subopposita* having a unique sesquiterpene skeleton. The structure of oppositol (3.) was determined by X-ray diffraction techniques.



3

Natural Compounds from Marine Organisms

Riverside
R/MP-5

James J. Sims,
William N. Fenical and
Philip C. Radlick

Many natural compounds isolated from marine algae are excellent bacteria fighters. A screening system helps to determine the efficiency of a variety of such compounds.

TABLE 1. Antibiotics from marine Algae.

Compound	Staph. aureus	Salmonella California	E. coli	Candida albicans	Mycobacterium smegmatis
Penicillin G	640>x>320	----	----	----	----
Streptomycin sulfate	10>x>	30>x>10	10>x	----	10>x
Chondriol	100>x>10	----	----	----	100>x>10
Pre-pacifenol	100>x>10	----	----	----	100>x>10
Laurinterol	5>x>1	----	----	100>x>10	5>x>1
Debromolaurinterol	50>x>10	----	----	50>x>10	50>x>10
Cycloeudesmol	50>x>10	100>x>50	----	50>x>10	50>x>10

x = concentration for complete inhibition after 48 hours of growth in μg/ml.

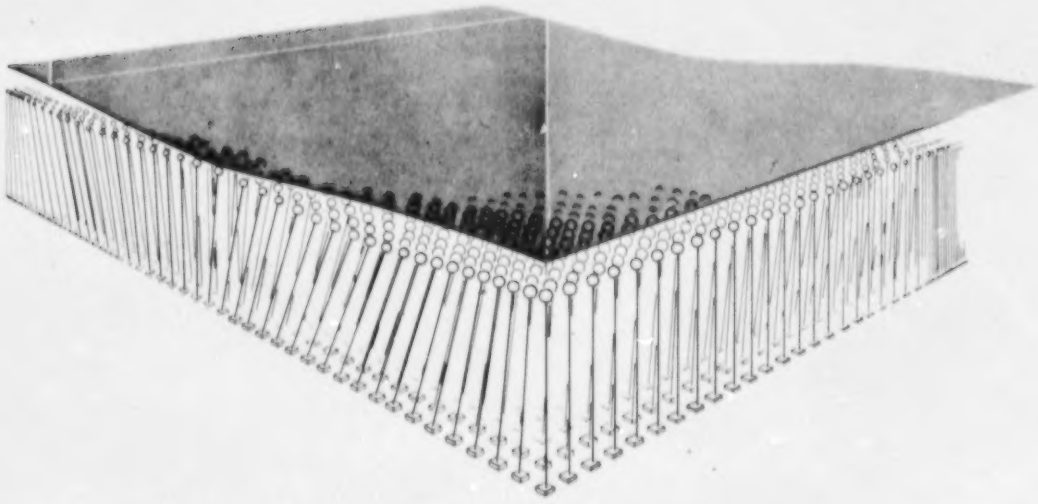
During this year we set up an antibiotic screen in order to be able to quickly evaluate the antimicrobial activity of pure compounds isolated from marine algae. A number of compounds were found to have excellent activity. A listing of the compounds found to have activity is given in Table 1.

Laurencia demands attention

The red algal genus *Laurencia* continues to occupy our attention. The compounds laurinterol and debromolaurinterol come from many species of *Laurencia* (table 1). We have investigated eight species so far and each contains a different major compound. We hope to be able to make some contributions to the taxonomy of *Laurencia* based on its chemical composition.

Cooperating Organizations
Merck, Sharp and Dohme Labs, Rahway, New Jersey
National Cancer Institute, N.I.H., Bethesda, Maryland
Searle Laboratories, Chicago, Illinois
University of Rhode Island School of Pharmacy

TETHERED FLOAT BREAKWATER SYSTEM



OCEAN ENGINEERING

Mapping and exploring the contours of the sea, designing and testing unmanned systems that can study depths no human could routinely sound and search; finding ways to measure, contain, dissipate and channel the energy of waves; and studying the properties of the sea floor itself, UC engineers are amassing the concepts and machinery to cope with the sea and to utilize it in many ways—for instance, as an energy source.

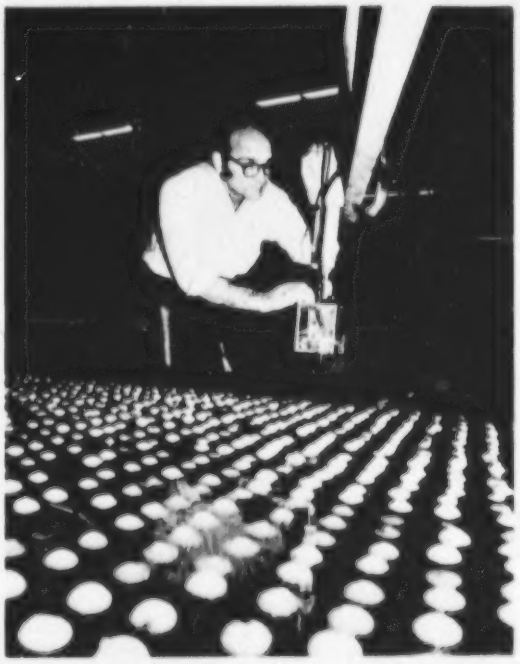
Wave Attenuation Studies

San Diego
R/E-1a

**John D. Isaacs and
Richard J. Seymour**

A tethered float breakwater system which dissipates wave energy is tested in miniature and leads to speculation that it could have a dizzying variety of applications, from protecting harbors to providing a patch of calm sea for offshore tanker unloading.

A study was undertaken for the California Department of Navigation and Ocean Development to evaluate locations for a full-scale experimental breakwater installation. "Report of Survey of Sites in California for Construction of Tethered Float Breakwaters for Harbors of Refuge" was issued in December 1972. In January 1973, Avalon Bay on Catalina Island was chosen as the preliminary site for such an experiment. A 1/60th scale model of Avalon Bay was constructed in the wave basin at the SIO Hydraulics Laboratory. An 1800-sphere tethered float array was installed to evaluate performance. It was found that the 29-row array (with a scale natural period of 9 seconds) dissipated approximately 65% of the energy in a broad spectrum wave field peaked at a scale period of 12 seconds, 85% of the energy at a scale period of 5 seconds (the anticipated storm wave peak period from Santa Ana wind conditions) and 95% of the energy at a scale peak of 3 seconds.



Tethered float breakwater model.

Time history of sphere motion

Verification of the response of a full-scale tethered sphere to ocean waves was required to enable the reliable extrapolation of medel array performance to real ocean applications. Therefore an 86 cm diameter spherical float was tethered subsurface in 10 m of water off Scripps Pier. A tiltmeter was attached to the anchor to measure the inclination of the tether in two planes. This provided a time history of sphere motion. The wave field was measured by a bottom-mounted pressure sensor. Wave direction was verified by a two-axis electromagnetic current meter mounted near the bottom. Data were returned to the Shore Processes Laboratory for recording by means of submarine cables and telemetry link.

Performance can be predicted

Data were recorded for a variety of wave conditions during the months of May and June 1973. The energy dissipation performance calculated from the measured statistics of relative motion from these experiments agrees well with scaled up laboratory data. Further, it was demonstrated that the linear drag model allows the effective prediction of this dissipation, given only the incident wave spectrum. This was an extremely important finding in that it shows that the performance of any array geometry can be predicted for any given wave climate.

Permission was obtained from the U.S. Navy to use 750 5-ft diameter steel net buoys for the initial breakwater experiment.

Wave-Powered Generator

San Diego
R/E-1b

**John D. Isaacs and
David Castel**

Too-calm seas "plague" researchers testing a wave-powered generator but enough information is gathered for design of a larger model of the apparatus.

The latest in a series of test runs of the wave powered generator was held during the period July 9-19, 1973 in the waters off Point Conception, California. As in the last run of April 1973, this experiment was conducted on the RV Ellen B. Scripps.

Model predictions agree with data

The purpose of this latest run, as was the aim of the previous ones, was to try and verify the theoretical model; in particular the non-linear effects which are most predominant in high swells were to be investigated. In the absence of the desired sea conditions complete veracity was not possible. However, enough information was gathered to establish the accuracy of the model for those sea conditions which were experienced. On the basis of results obtained it is now possible to extrapolate and predict with a high degree of confidence the performance of a particular generator in a particular seaway. In general there was good agreement between model predictions and data gathered. For example in six feet significant waves the pump produced a mean pressure of 7.5 psi in the accumulator tank (under flow conditions and through a ½" discharge nozzle) for a theoretical power output (in the absence of a turbine) of 60 watts. For the same system parameters and swell conditions, the model predicts a pressure of 7.5 psi showing good agreement with the actual results. Optimization of accumulator tank size for the above conditions would have resulted in a power output of 610 w. Complete evaluation of the system is currently under way but on the basis of results obtained thus far, it can be shown that a generator with a 300 ft. long, 15 ft. diameter pipe will yield an appromimate output of 300 KW in 8 ft. significant waves.

Pending the outcome of the final evaluation a large model might be built for further evaluation and use in the trade winds or similar area.

Unmanned Seafloor Work Systems

San Diego
R/E-2

Victor C. Anderson

Utilization of the sea floor, harvesting its resources and monitoring, inspection and enforcement to protect the public interest require man to extend his work capability deeper and deeper into the ocean. The ORB-RUM work system provides a unique and efficient platform and vehicle to perform remotely manned studies.

During the year September 1, 1972, to August 31, 1973, the ORB-RUM system (Oceanographic Research Buoy-Remote Underwater Manipulator) has seen an additional 15 days of operations at sea at three sites at depths of 138 to 1231 meters. The work at these sites has included installation of acoustic navigation transponder fields, placement of sonar targets with successive vehicle passes to determine high resolution narrow beam sonar performance, location-recovery repair and reinstallation of sea floor mounted sensors and trafficability studies with related sediment sampling.

Rock drill extends capability

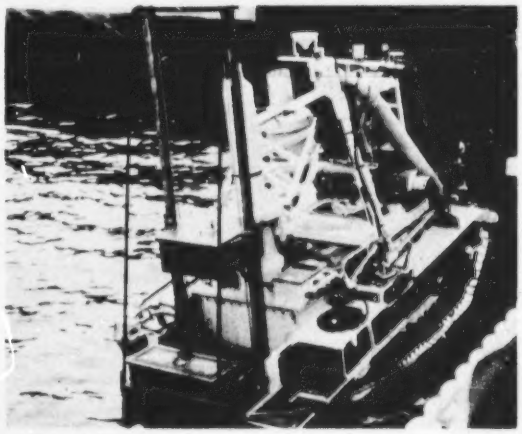
A rock drill has been designed, fabricated and fitted to the RUM vehicle this year to extend the work capability. The drill is designed to obtain documented oriented cores approximately 4.5 centimeters in diameter and up to 3 meters in length.

The design approach was an adaptive one in order to make maximum use of existing control and instrumentation systems in the RUM vehicle and to minimize the amount and

complexity of the new hardware being added. DC motors were used to power the drill so that RUM propulsion controllers and telemetry could be used for control and instrumentation. Controls provide for approximately 0 to 80 Kilogram meters of torque and 0 to 900 Kilograms of hauldown force on the drill. Torque, hauldown force and depth of drill penetration are telemetered to the remote operator's console.

Results of efficiency studies

By January, 1972, the ORB-RUM configuration and procedures were considered sufficiently stable for the initiation of time analysis of all missions and sub-tasks. Documentation of these missions through August 1973 covers 260 hours of purposeful operations on the sea floor. These data have become the basis for an investigation into the efficiency of remotely controlled general purpose sea floor work systems. The investigation will consider surface transits, mooring, launch and retrieval of the system through the sea surface, effectiveness of navigation and traverse on and near the bottom, sensing of the bottom environment, and the actual performance of manipulative tasks. Results will be compiled and submitted for publication early in 1974. Additional input from missions undertaken after August 1973, in particular an initial evaluation of the aforementioned rock drill concept at 545 meters depth and an extensive biological study involving a large variety of manipulative tasks at 1212 meters depth, will be included in the study.



Rock drill rig can be seen at the rear of the vehicle as Rum enters the water during loading operations.

A small joint cooperative study effort, initiated with Lockheed Corp. last year, to develop a methodology for the economic analysis of sea floor work systems, was continued through this year. In connection with this study, a survey of past and present owner operators of work vehicles has been conducted. The response has been encouraging with over 70% of those surveyed supplying substantial data on costs and work experience.

Engineering Properties Of Seafloor Sediments

Iraj Noorany

San Diego
State University
R/E-3

Determining the effects of sampling on the engineering properties of sea-floor sediments may help those designing offshore foundations and underwater installations as well as developers of tidelands, manmade near-shore islands, marinas and recreational facilities.

This part of the program was a continuation of the cooperative work between the Soil Mechanics Laboratory at SDSU and the Marine Physical Laboratory of SIO, UCSD. The purpose of these studies was to make in-place measurements of the sediment properties using the SIO tracked crawler RUM, and to recover sediment cores to be tested in the laboratory. The comparison between the results of the laboratory tests and the field measurements provide a basis for the evaluation of the effects of sampling on engineering properties of sea-floor sediments. Furthermore, the collected data on the engineering properties of these sediments becomes a much needed source of information for engineers, scientists and governmental agencies interested in the condition of the sea floor in the near-shore region of the Pacific.

Measuring sea-floor trafficability

The *in situ* tests consisted of vane shear and cone penetrometer tests, as well as measurements of the sea-floor trafficability under the tracks of RUM. Sediment cores

were taken using RUM's two foot-long sampler. In addition to the near shore samples, a series of clay samples taken by Kennecott Exploration Inc. were also tested for their engineering properties. These samples were taken by means of a spade corer from the deep-sea Pacific.

Samples classified

The laboratory investigations were performed at the Soil Mechanics Laboratory of SDSU under the supervision of I. Noorany, with the assistance of G. Luke and E. Buchanan. Physical properties of the sediments, including water content, unit weight, dry density, specific gravity, grain size distribution and Atterberg Limits, were determined. The samples were classified in accordance with the Unified Classification System. Vane shear and triaxial compression tests were performed to determine shear strenght, and consolidation tests were made to measure the compressibility of the sediments.

High pressure triaxial testing

In order to investigate the effects of sampling on the engineering properties of sea floor sediments, a high pressure triaxial testing facility was designed. This system is presently being assembled for operation under pressures up to 10,000 psi. The system is designed to permit simulation of the process of stress change caused by sampling of sea floor soils.

Underwater Cable Dynamics

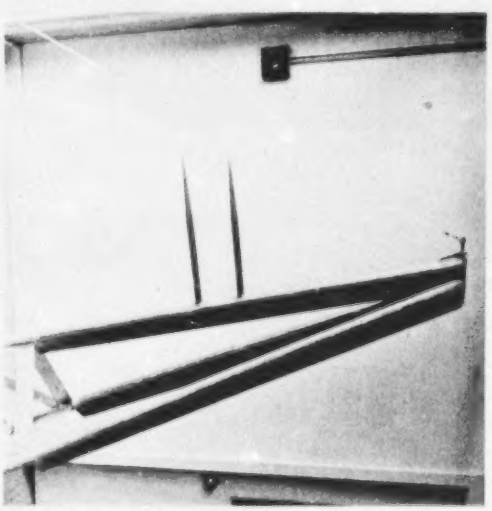
Berkeley
R/E-5

William C. Webster

When a cable-supported oceanographic device is towed at slow speed or is exposed to a water current, it has been observed to strum. This strumming appears to greatly increase the drag of the cable and can introduce unwanted vibrations in the suspended device. Our research here is aimed at determining the causes of the strumming and, in particular, the hydrodynamic loading of the cable resulting from the strumming.

During the year 1972-1973 considerable progress was made in developing an experimental apparatus and procedure to investigate strumming. A test facility was developed in which an eight-foot length of cable was towed down the Ship Model Towing Tank at the Richmond Field Station. One end of the cable was attached to the towing carriage, the other end to a streamlined support underwater, near the bottom of the towing tank. Motions of the cable were recorded by means of a high speed motion picture camera mounted on the carriage. For each test condition, two movies of the cable motion were taken. The first was across the model tank. These pictures were obtained by mounting a mirror on the towing carriage placed so that the camera could view the cable through the windows on the side of the tank. The second of these movies was taken straight down at the cable through a glass bottom boat. Both sets of movies were obtained at a camera speed of 500 frames per second, since the observed cable strumming was at a frequency of about 50 Hz.

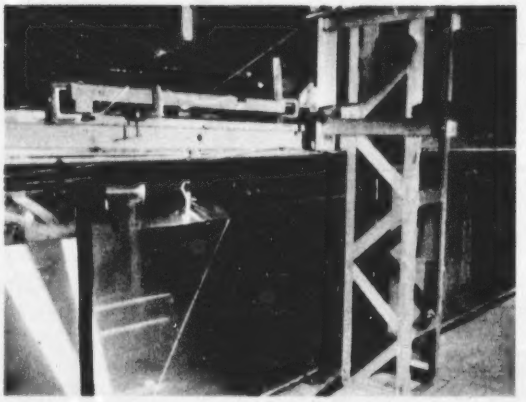
During this year experiments were performed for a variety of cable tensions and carriage speeds. Tests were also performed on calbes for which the lower end was left free and not attached to a support. In this situation, a ball-shaped weight was attached to the lower end of the cable. As a result of



Streamlined cable support apparatus showing reference strings.

this test program, a large mass of movie-recorded data on the strumming motions of cables have been accumulated.

During the 1973-1974 year, this data will be quantified by measuring the position of many points on the cable for each frame of film. These displacements will be inserted into the theory in order to obtain estimates of the space and time variations of the hydrodynamic loads on the cable.



Test set-up showing tank windows and mirror, Underwater Cable Dynamics project.

Studies of Recent History Of California Coastal Lagoons

San Diego
R/E-6

John D. Isaacs

Peta J. Mudie and James R. Moriarty

A multidisciplinary approach is being used to interpret the recent history of California's coastal lagoons. Geological, archaeological and historical evidence is being examined to determine the extent to which the lagoons have been changed by European settlement.

Planning for the land-use, management and development of coastal lagoons in California has been hampered by controversy over the natural conditions of these wetland areas. Conservationists argue that the lagoons are important fish nurseries, shellfish grounds and wildlife refuges, and that they have been degraded by man-induced changes. Developers reason that the lagoons are dying from geological old-age and that it would be beneficial to convert the malodorous, eutrophic swamps to areas supporting a diversity of uses other than natural resource preservation.

Perspective on controversy over natural history

The purpose of the coastal lagoon history study is to lend perspective and rational context to this controversy by ascertaining what has been the natural state of these areas in recent times.

The picture that emerges is that a shell gathering culture seems to have persisted around the lagoons, at least intermittently, for nine millenia.

Some of the fish species commonly represented in the middens are characteristic of sheltered bays, lagoons or estuaries, where they presumably could be caught more readily than those of the open sea. All available archeaological evidence indicates that the coastal lagoons of Southern California were the foci of prehistoric human interaction and settlement, and were subjected to the most intensive levels of use applied to any marine waters.

Cooperating Organizations
San Diego Museum of Man
University of San Diego
Lowie Museum
University of California, Berkeley
University of California Archaeological Survey

Composite Materials For Ocean Construction

Alan S. Tetelman

Although concrete is the most economical structural material available, its low tensile strength has limited its application to compressive loading situations. Recent investigations have shown that the tensile strength can be increased if the concrete is impregnated with a polymer or reinforced with randomly oriented steel fibers.

The study at UCLA was concerned with discovering the strengthening mechanisms of the two types of reinforcement and the effect of sea water on them. From three-point-bend tests on notched bars, we have found that the work of fracture, G_F, of the fiber-reinforced concrete can be quantitatively described by a combination of fiber pull-out and a fiber shear model. Similarly, the fracture model of a continuously aligned composite can be used qualitatively to describe the relationship between fracture strength and fiber reinforcement.

Increasing strength of concrete

Both the work of fracture, G_F, and the fracture toughness, K_{IC} have been shown to increase with increasing amounts of polymethyl methacrylate (PMMA) added to the concrete. For example, an 8.5 wt.% addition of PMMA resulted in an increase in G_F by a factor of three, and K_{IC} by a factor of four. The PMMA has been found to increase the strength of the concrete by two mechanisms. First of all, the PMMA strengthens the cement matrix by filling the pores and microcracks which form during hydration and drying. Secondly, the bond strength between the cement paste and aggregate is increased to such an extent that the crack is no longer able to propagate around the aggregate as in plain concrete, but is forced to propagate through it.

Boiling sea water destroys bond

In order to determine how these strengthening mechanisms are affected by sea water, notched bars of plain polymer-impregnated, and fiber-reinforced concrete were placed in a closed environment of boiling sea water for up to six months. The strengths of the plain and fiber-reinforced concrete were unaffected by the exposure. The strength of the polymer concrete, however, decreased to one-third of its original value. An examination of the fracture surface with scanning electron microscope revealed cracking at the polymer-cement-paste interface. It was concluded that the interfacial cracking resulting from the exposure to boiling sea water destroyed the polymer-cement bond, thereby enabling the crack to propagate along the path of least resistance at a very low stress level.

Gabions show promise

Although the work at UCLA was concerned mainly with concrete, the properties of the wires in "gabions" were also studied. Gabions consist of polyvinyl-chloride-coated wire mesh that has been shaped into rectangular blocks, filled with rocks, and joined together to form a monolithic structure. Microstructural analysis of a wire exposed to sea water for ten years failed to reveal any evidence of localized oxidation. Micro-hardness tests performed on this wire indicate that the tensile strength was comparable to that of the unexposed wire.

In conclusion, we believe that fiber-reinforced concrete, as well as gabions show great promise as materials which can be used in ocean construction.

PROGRAM SUMMARY

PROGRAM DEVELOPMENT	FY71	FY72	FY73
PROGRAM MANAGEMENT			
Management and Program Development (Shor)	R/O	O	O
New Projects (Shor)	-	N	O
EDUCATION/TRAINING			
Graduate Education in Applied Ocean Science (Anderson)	O	O	C
Graduate Education in Marine Biomedicine (Elsner)	N/C		
Sea Grant Trainees (Shor)	O	O	O
Scientific Diving Supervisor Training (Stewart)	N	C	
Undergraduate Training in Marine Technology (Flittner)	N	O	O
ADVISORY			
Ocean Education for the Public (Wilkie)	N	O	O
Marine Extension Services (Cummings)	-	N	O
Publications and Public Advisory Services (Wick)	-	-	N
Ocean Engineering Data Center (Johnson)	-	-	N
Extension Education in Oceanography for Engineers: Survey of Need, Planning, and Development of Course Sequence (Chamberlain)	N/C		
Geophysical and Geological Data Center for Information on Petroleum Resources (Chase)	N	C	
Support of Albacore Advisory Service Radio Broadcasts (Shor)	N/C		
Improvement of Methods of Predicting Sea-Surface Temperatures (Gibson)	N	C	
Marine Advisory Services Expansion (Flittner)	N	C	
COASTAL ZONE STUDIES			
Environmental Conflict Identification (Twiss)	-	N	O
Economics of Marine Resources Decision Modeling (Sullivan)	-	N	O
Physical Criteria for Coastal Planning (Inman/Van Atta)	N	O	O
Biological and Ecological Studies of Normal Populations, Natural Variability and Effects of Environmental Changes in the Nearshore Zone (Newman)	N	C	
Ecological Studies of the Nearshore Zone (Fager/Dayton)	N	O	O
Ecology of Santa Cruz and San Mateo County Coasts (Doyle)	-	N	O
Natural Seepage in the Santa Barbara Channel: Physiochemical Aspects (Mikolaj)	-	N	C
An Investigation of the Seismicity and Earthquake Hazards of the Santa Barbara Channel Area (Sylvester)	-	N	C
Sea Coast Planning Project (Hetrick, et al.)	-	N	C
Monitoring of Pollution Parameters in San Francisco Bay (Wilde)	-	-	N
Recreational Resources of Los Angeles County Coast (Egstrom)	-	-	N
Trace Metal Analysis of Oily Beach Pollutants in the Santa Barbara Channel (Mikolaj)	-	N	C

PROGRAM DEVELOPMENT	FY71	FY72	FY73
FISHERIES/AQUACULTURE			
Uses of Waste in Aquaculture (Cooper/Holmes)	-	-	N
Rearing of Larval Fishes (Lasker)	N	O	C
Economics of Aquaculture (Johnston)	-	-	N
Aquaculture of the American Lobster (Shleser)	-	N	O
Studies of Vertical Migration of Zooplankton (Enright/Isaacs)	N	C	
An American Lobster Fishery in California (Ford)	N	O	C
California Spiny Lobster Growth (Dexter)	O	O	T*
Historical Levels, Areas, and Routes of Pesticides in the Plankton and Fish of the California Current (Longhurst/Lasker)	N	C	
Protective Measures for Lobster Aquaculture (Mathewson)	O	O	R
Evaluation of the California Spiny Lobster Fishery and Related Population Characteristics During a Period of Reduced Fishing Effort (Farris)	N	C	
Abalone Culture (Leighton/Wilson)	-	N	C
Seaweed Resource Management (Cultivation) (Neushul)	-	N	O
Gelidium Resource Management (Barilotti)	-	-	N
Salt-Tolerant Plants (Epstein)	-	-	N
Fishes of the Santa Barbara Kepl Forest (Ebeling)	O	O	C
The Juvenilizing Factor in Crustacean Eyestalks (Faulkner/O'Connor)	N	C	
Ecology of Benthic Herbivores in the Sea (Connell/Murdoch)	O	C	
Ecosystem Studies and Maricultural Potentialities of a Coastal Lagoon (Holmes)	N	C	
Culture, Behavior and Physiology of the California Spiny Lobster *Panulirus interruptus* (Chase/Childress)	C		
MARINE PRODUCTS			
Food Uses of Marine Lipids (Olcott)	-	N	O
Studies of Fish Muscle Proteins (Brown)	-	N	O
Natural Fermentation of Marine Products (Crisan)	-	N	O
Pharmaceuticals from Marine Organisms (Faulkner)	N	O	O
Natural Compounds From Marine Organisms (Sims)	-	N	O
OCEAN ENGINEERING			
Enhancement of Natural Marine Productivity by Artificial Upwelling (Isaacs/Schmitt)	N	C	
Wave Power (Isaacs) a) Wave Attenuation Studies b) Wave-Powered Generator	-	-	N
Unmanned Sea Floor Work Systems (Anderson)	N	O	C
Engineering Properties of Sea Floor Sediments (Noorany)	-	N	O
Synthesis of Forces on Marine Structures (Paulling)	-	N/C	
Underwater Cable Dynamics (Webster)	-	N	C
New Applied Developments (Isaacs)	N	O	O
Acoustic Holographic System for Underwater Search (Wade)	-	N/C	
Composite Materials for Ocean Construction (Tetelman)	-	N	C

N = New Project
O = Ongoing Project
R = Restructured Project
C = Completed Project
T = Terminated Project
*No Final Report

ACTIVITY BUDGET SHEET

	NOAA Grant Funds	Matching Funds
Program Management		
Program Administration	131,815	102,513
Project Development	11,625	-0-
Marine Education and Training		
College level (Curricular Dev.)	4,000	80,808
College level (Sea Grant Trainees)	232,000	-0-
Vocational Marine Tech. Training	21,033	10,364
Other (Public Education)	12,623	16,658
Advisory Services		
Extension Programs	81,018	62,302
Other Advisory Services (Data Center)	16,708	6,900
Advisory Services-Publications	36,588	-0-
Marine Resources Development		
Aquaculture	383,054	169,806
Living Resources (Other)	37,600	14,225
Marine Biomedicinals & Extracts	28,187	32,140
Marine Law and Socio-Economics	12,434	17,453
Marine Technology Research & Development		
Ocean Engineering	199,473	100,733
Resources Recovery & Utilization	73,729	50,283
Marine Environmental Research		
Research and Studies in Direct Support of Coastal Management Decisions	131,282	86,383
Ecosystems Research	47,022	45,621
Pollution Studies	47,627	28,812
Applied Oceanography	142,202	36,680
TOTAL:	$1,650,000	$861,681

SEA GRANT PUBLICATIONS

Barr, Roderick A. 1973. The nonlinear dynamics of cable systems. University of California Sea Grant Publication No. 4. 153pp.

Chiu, Hin. 1973. Diffraction of water waves by a submerged circular cylinder. University of California Sea Grant Publication No. 5. 34pp.

Danglar, Edward. 1973. Sea floor work economics. University of California Sea Grant Publication No. 25. 38pp.

Fisher, Robert L. and Paul J. Liebertz. 1973. Rock dredging in deep-sea areas. *The Scripps Institution of Oceanography Marine Technicians Handbook*. Sea Grant Publication No. 23. 39pp.

Hetrick, Carl C. 1973. The Santa Barbara coastal zone and environmental policy survey: item response survey. 103pp.

Johnston, Warren E. and Don W. Collinsworth. 1973. An annotated bibliography of economic evaluations of the aquaculture of selected crustaceans and mollusks. University of California Sea Grant Publication No. 2. 62pp.

Mikolaj, Paul. 1973. Report on the composition of oil from the region of new hydrocarbon upwelling in the Santa Barbara Channel. 9pp.

Riedel, William, Phyllis Helms and Thomas Walsh. 1973. The curating of marine geological samples. *The Scripps Institution of Oceanography Marine Technicians Handbook*. 31pp.

Sea Grant. 1973. University of California Sea Grant Program Directory. 1972-73. Sea Grant Publication No. 22. 12pp.

Sea Grant. 1973. University of California Annual Report 1971-72. 102pp.

Sea Grant. 1973. University of California Sea Grant Programs Cumulative Directory, 1968-1973. Sea Grant Publication No. 27. 33pp.

Sea Grant U-California. Newsletter. Vol. 1, No. 1, March, 1973. 2pp.

Sea Grant U-California. Newsletter. Vol. 1, No. 2, May, 1973. 2pp.

Sea Grant U-California. Newsletter. Vol. 1, No. 3, July, 1973. 2pp.

Sorensen, Jens and Mitchell Moss. 1973. Procedures and programs to assist in the environmental impact statement process. Sea Grant Publication No. 27. 38pp.

Sorensen, Jens and Marie Demers. 1973. Coastal zone bibliography: citations to documents on planning, resources management and impact assessment. University of California Sea Grant Publication No. 8. 88pp.

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1972-73

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Editor's note: Supplementary material and references for individual projects are available at the Sea Grant Publications Office. See address below.

On behalf of the University of California, President Charles J. Hitch (right) and Scripps Institution of Oceanography Director William A. Nierenberg (center), also chairman of the UC Sea Grant Co-ordinating Council, accept the Sea Grant College plaque from Dr. Robert M. White (left), NOAA Administrator.

At opening ceremonies for a new Shore Processes Laboratory (left to right), former UC Sea Grant Program Manager Dr. George G. Shor, Jr., associate director of SIO, and J. D. Frautschy, assistant director of SIO and current Program Manager, talk with California's Senator John V. Tunney. The laboratory is north of Scripps' famous pier.

Designed and edited by Barbara Ann Firger

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